US011456114B2

(12) **United States Patent**
Muneuchi

(10) **Patent No.: US 11,456,114 B2**
(45) **Date of Patent: Sep. 27, 2022**

(54) **SURFACE-MOUNT INDUCTOR AND MANUFACTURING METHOD THEREOF**

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

(72) Inventor: **Keita Muneuchi**, Nagaokakyo (JP)

(73) Assignee: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1129 days.

(21) Appl. No.: **16/019,399**

(22) Filed: **Jun. 26, 2018**

(65) **Prior Publication Data**

US 2018/0308628 A1 Oct. 25, 2018

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2016/085626, filed on Nov. 30, 2016.

(30) **Foreign Application Priority Data**

Dec. 28, 2015 (JP) JP2015-256012

(51) **Int. Cl.**
H01F 27/29 (2006.01)
H01F 17/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01F 27/292*** (2013.01); ***H01F 17/04*** (2013.01); ***H01F 27/2823*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01F 27/292; H01F 17/04; H01F 41/0246
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0206089 A1* 11/2003 Shikama H01F 17/045 336/221
2013/0255071 A1* 10/2013 Muneuchi H01F 41/02 29/605
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2001-052937 A 2/2001
JP 2005-116708 A 4/2005
(Continued)

OTHER PUBLICATIONS

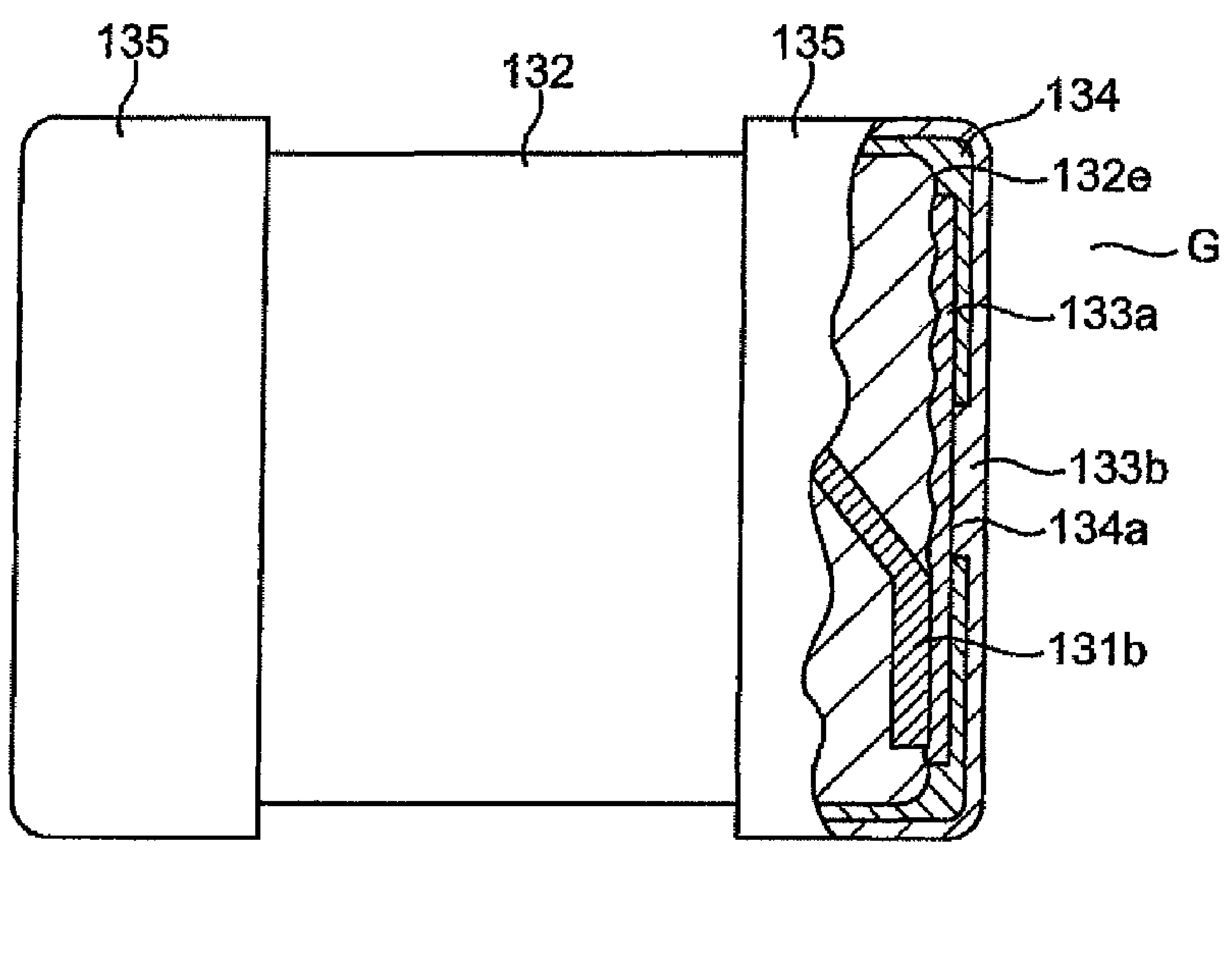
International Search Report issued in PCT/JP2016/085626; dated Feb. 21, 2017.
(Continued)

Primary Examiner — Elvin G Enad
Assistant Examiner — Malcolm Barnes
(74) *Attorney, Agent, or Firm* — Studebaker & Brackett PC

(57) **ABSTRACT**

A surface-mount inductor comprises a molded body containing a metal magnetic powder; at least one coil buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body; and an external terminal formed over an exposed surface of each of the lead-out end parts. A metal magnetic powder exposed portion is formed at least around the exposed surface. The external terminal at least includes a first plating layer formed over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part, and a conductive paste layer formed on the first plating layer and made of a solidified conductive paste. Consequently, the surface mount inductor comprises an external terminal having high connection reliability.

9 Claims, 13 Drawing Sheets



(51) **Int. Cl.**

H01F 41/02	(2006.01)
H01F 41/10	(2006.01)
H01F 27/28	(2006.01)

(52) **U.S. Cl.**

CPC ***H01F 27/2828*** (2013.01); ***H01F 41/0246*** (2013.01); ***H01F 41/10*** (2013.01); *H01F 2017/048* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0307655	A1*	11/2013	Saito	H01F 17/043 336/83
2014/0338185	A1*	11/2014	Muneuchi	H01F 41/066 29/605
2015/0099115	A1*	4/2015	Maeda	H01F 27/255 252/62.53

FOREIGN PATENT DOCUMENTS

JP	2013-211333	A	10/2013
JP	2014-225590	A	12/2014
JP	2016-058418	A	4/2016
KR	2001-0067075	A	7/2001
KR	2013-0139993	A	12/2013
KR	2014-0135644	A	11/2014
WO	2012/105489	A1	8/2012

OTHER PUBLICATIONS

International Preliminary Report On Patentability and Written Opinion Issued in PCT/JP2016/085626; dated Jul. 3, 2018.

An Office Action mailed by the Korean Patent Office dated Jul. 22, 2019, which corresponds to Korean Patent Application 10-2018-7018016 and is related to U.S. Appl. No. 16/019,399.

* cited by examiner

Fig.1

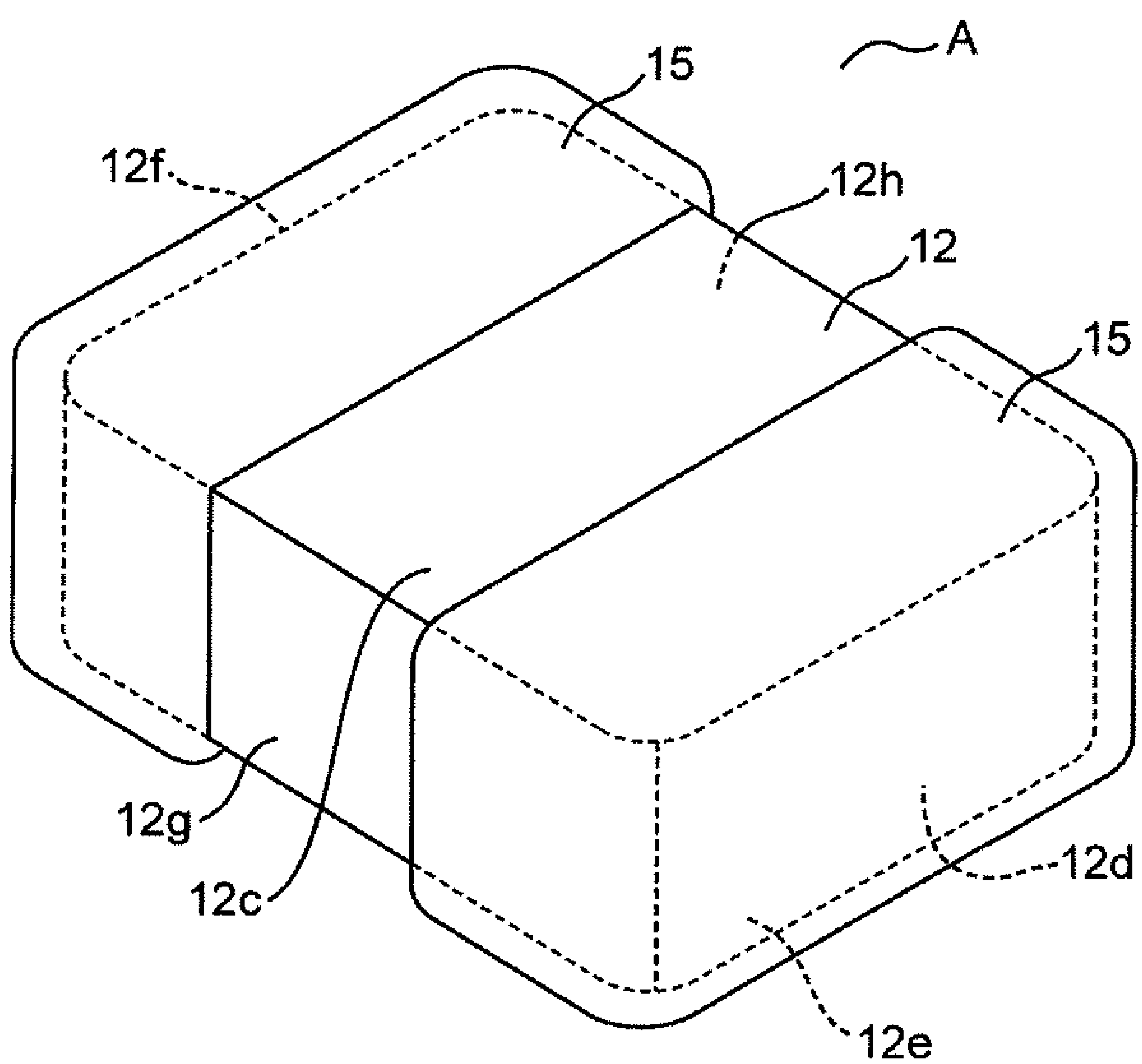


Fig.2

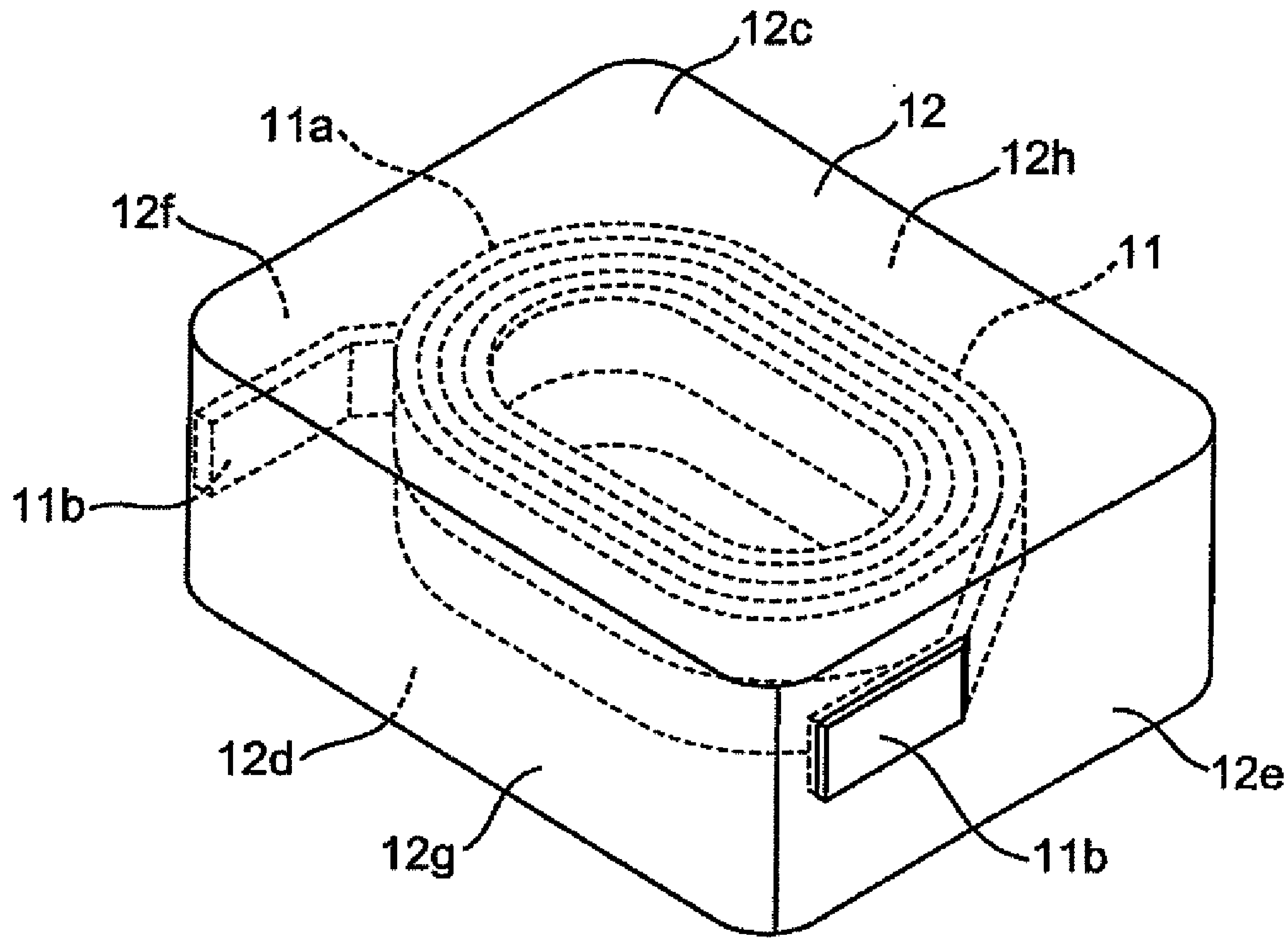


Fig.3

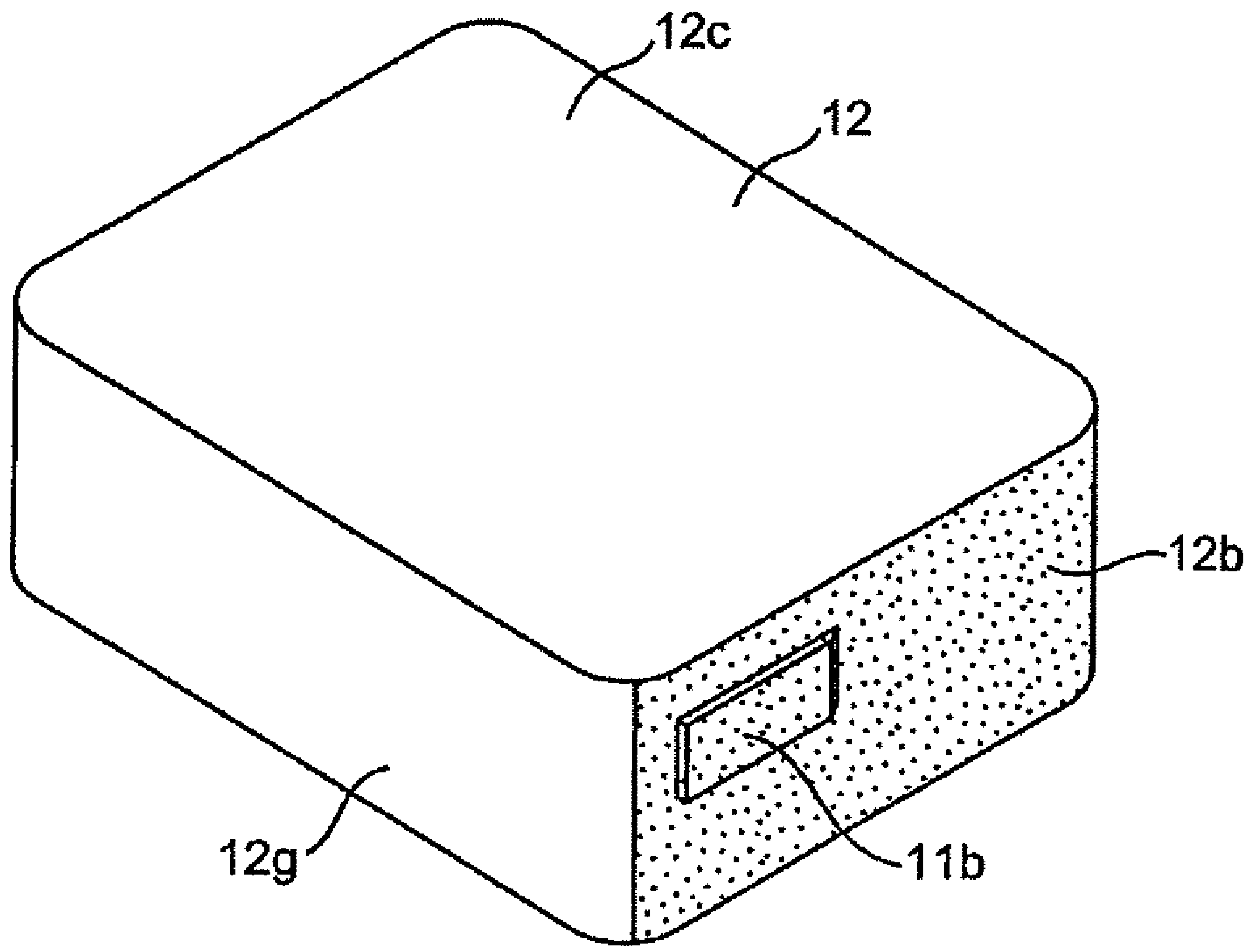


Fig.4

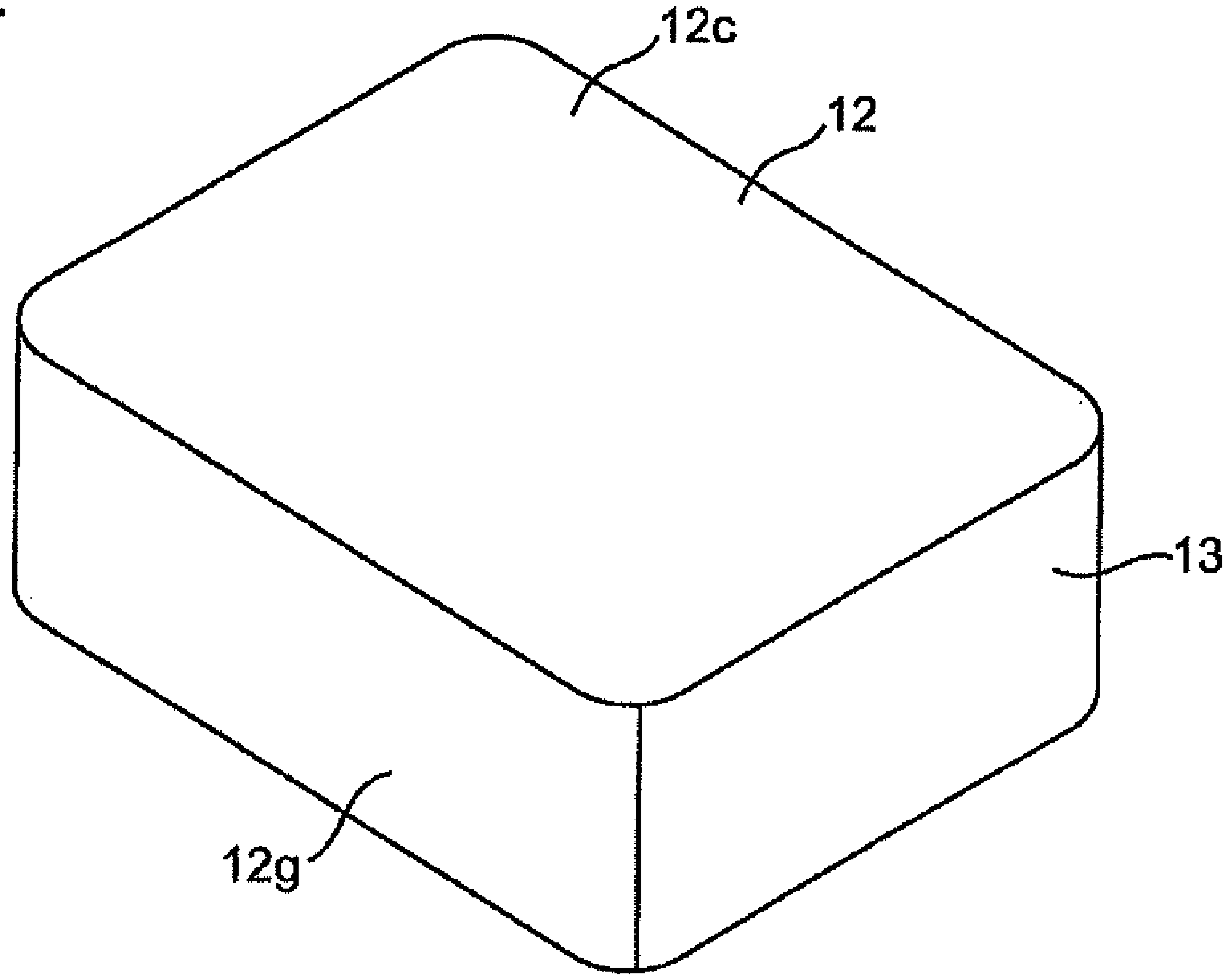


Fig.5

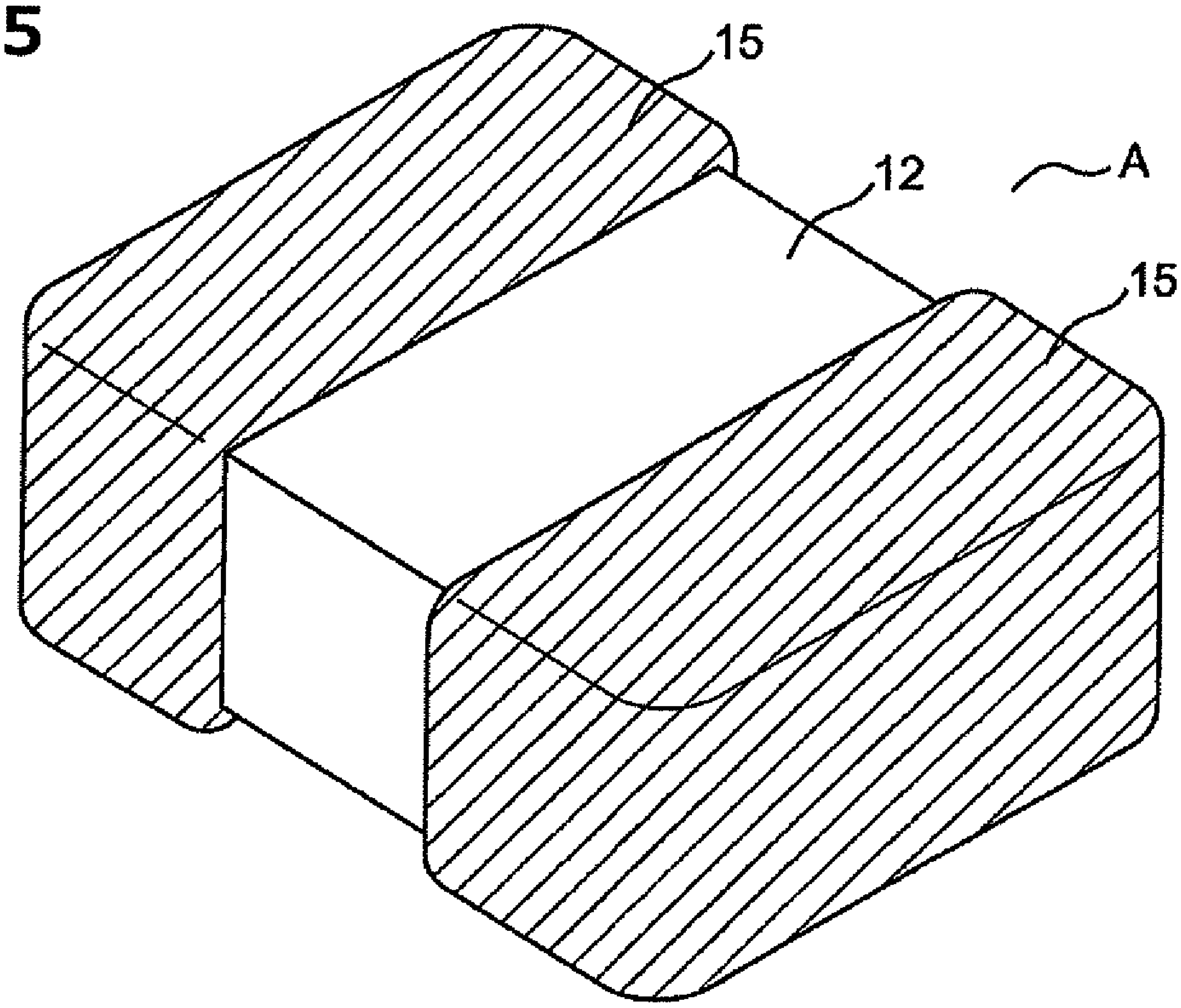


Fig.6

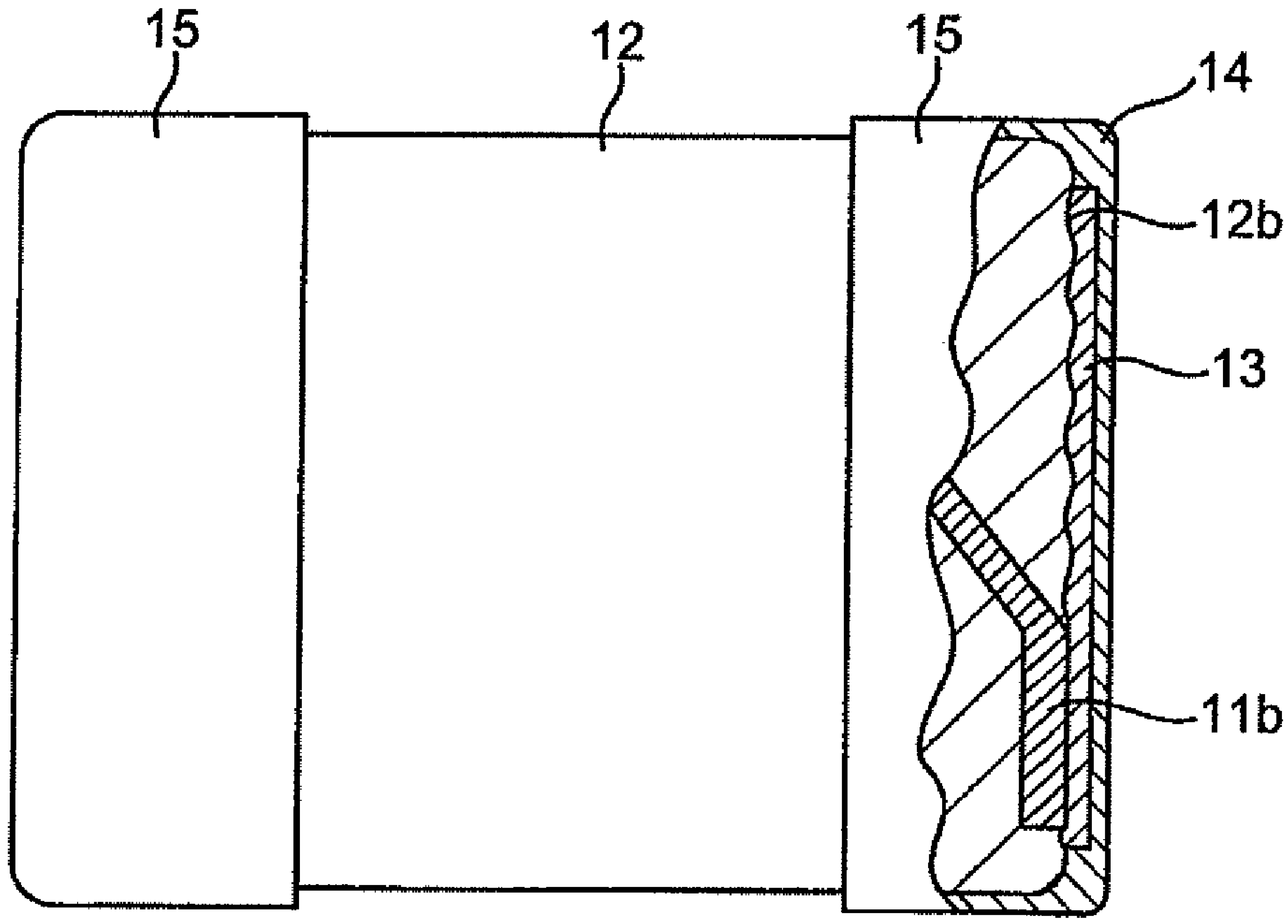

15
12
15
14
12b
13
11b

Fig.7

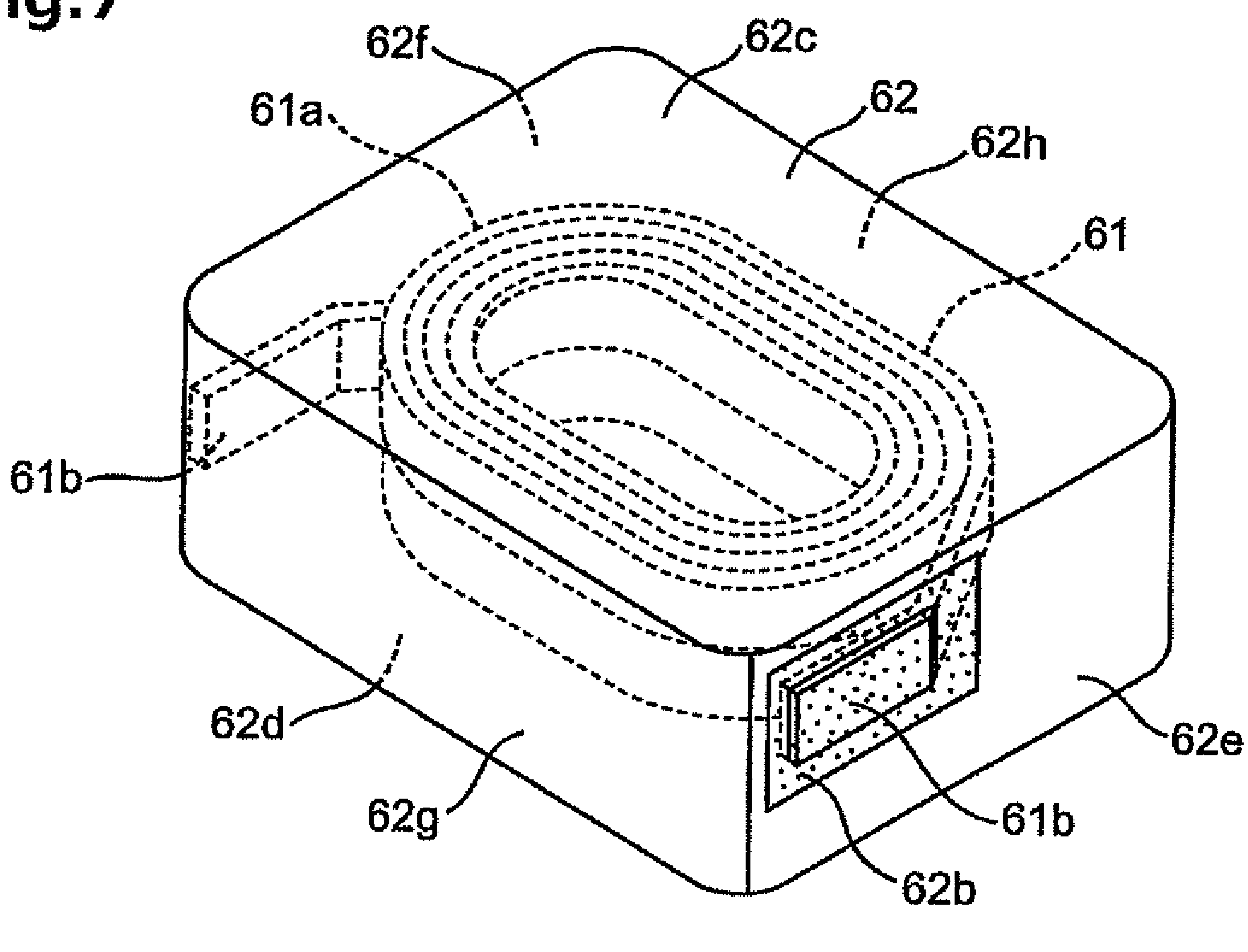

62f
62c
62
61a
62h
61
61b
62d
62e
62g
61b
62b

Fig.8

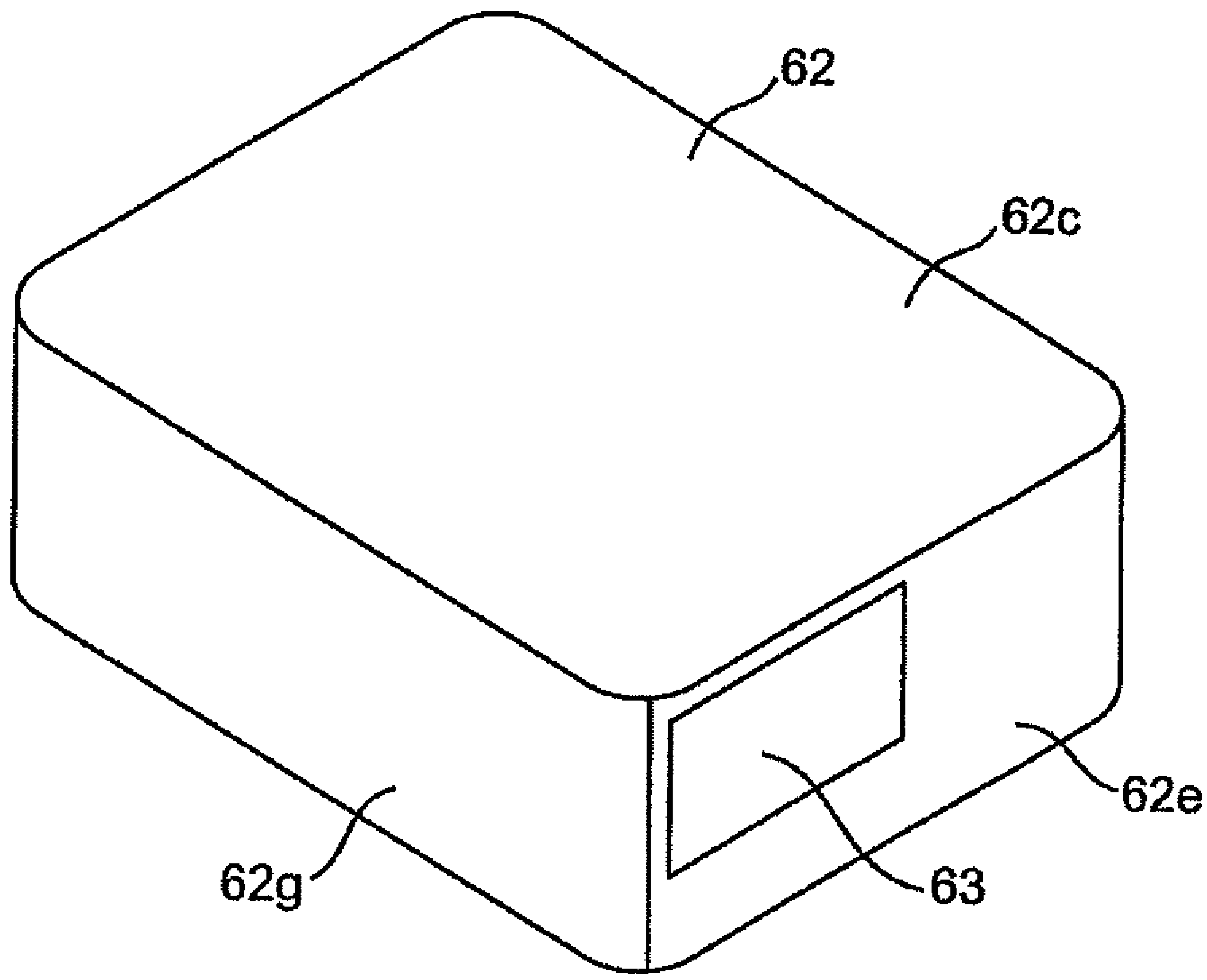


Fig.9

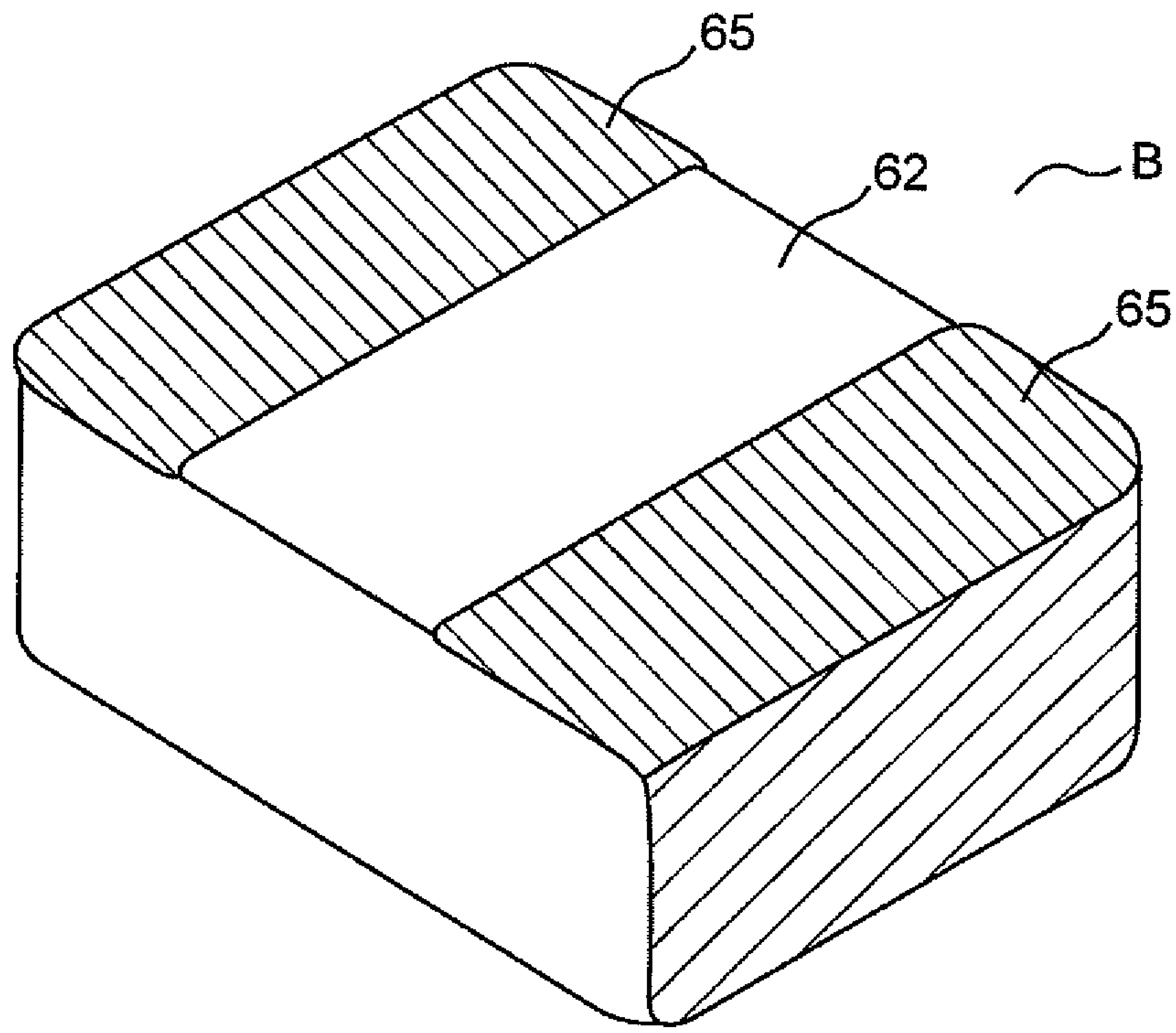


Fig.10A

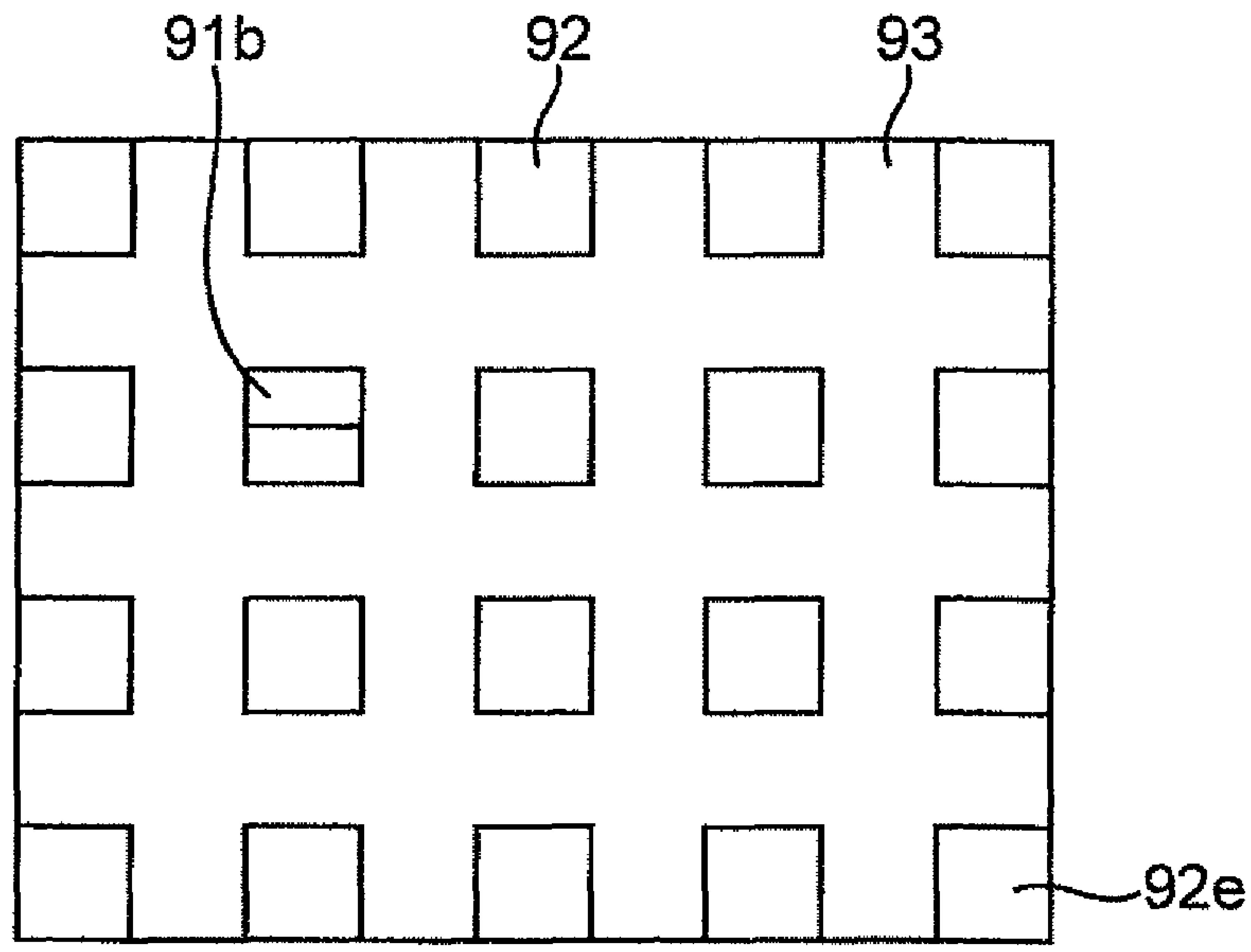


Fig.10B

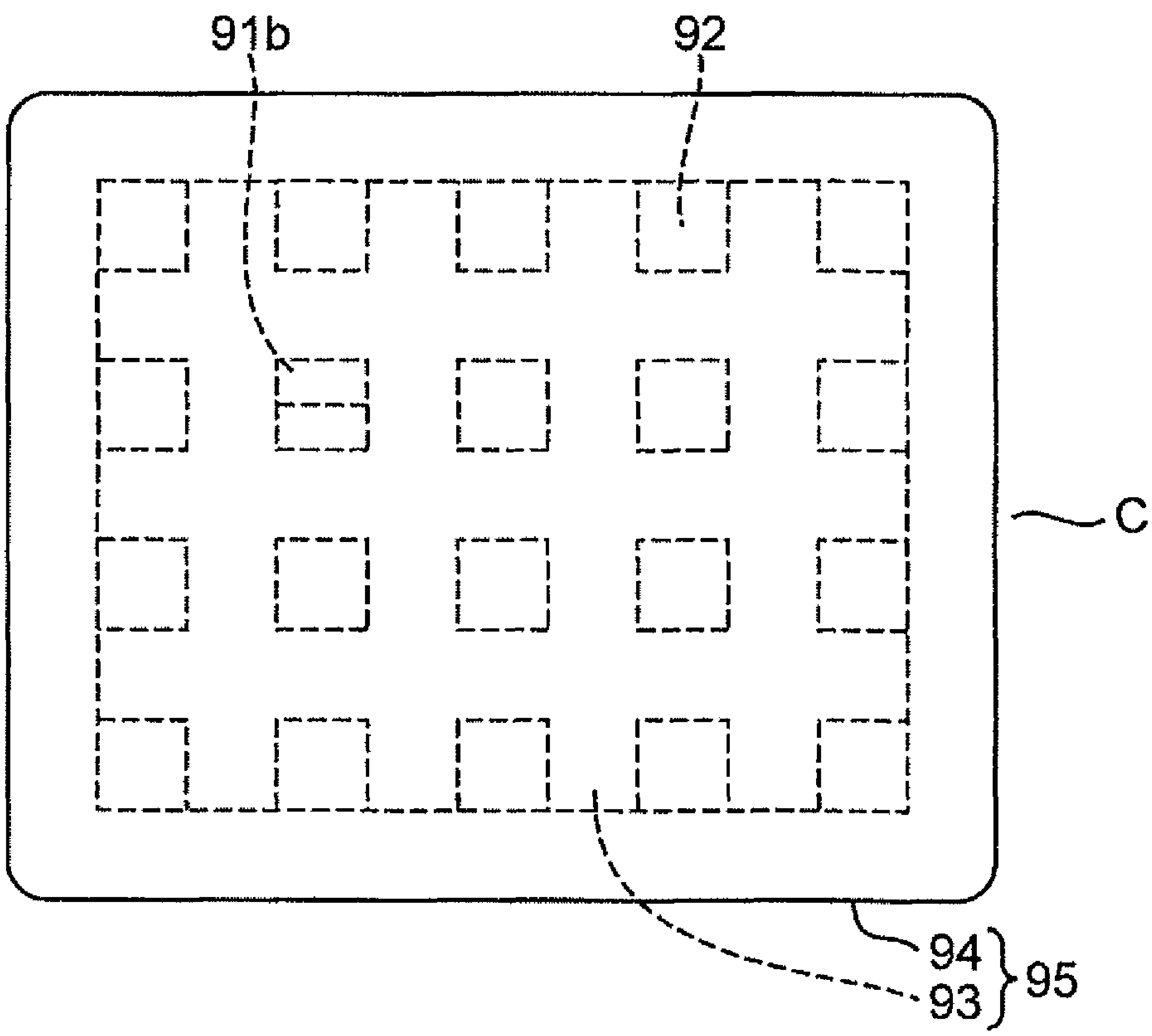


Fig.11A

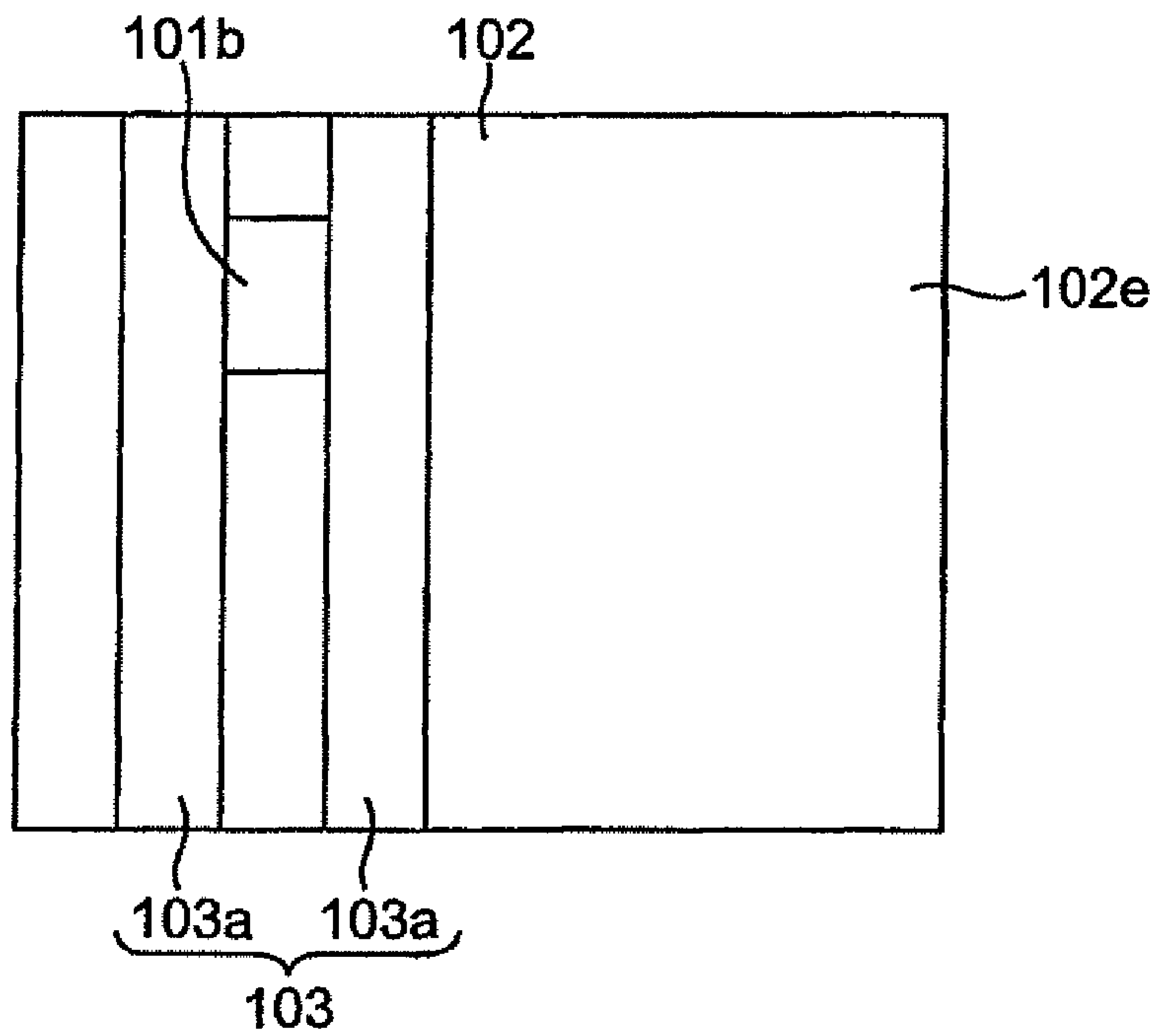


Fig.11B

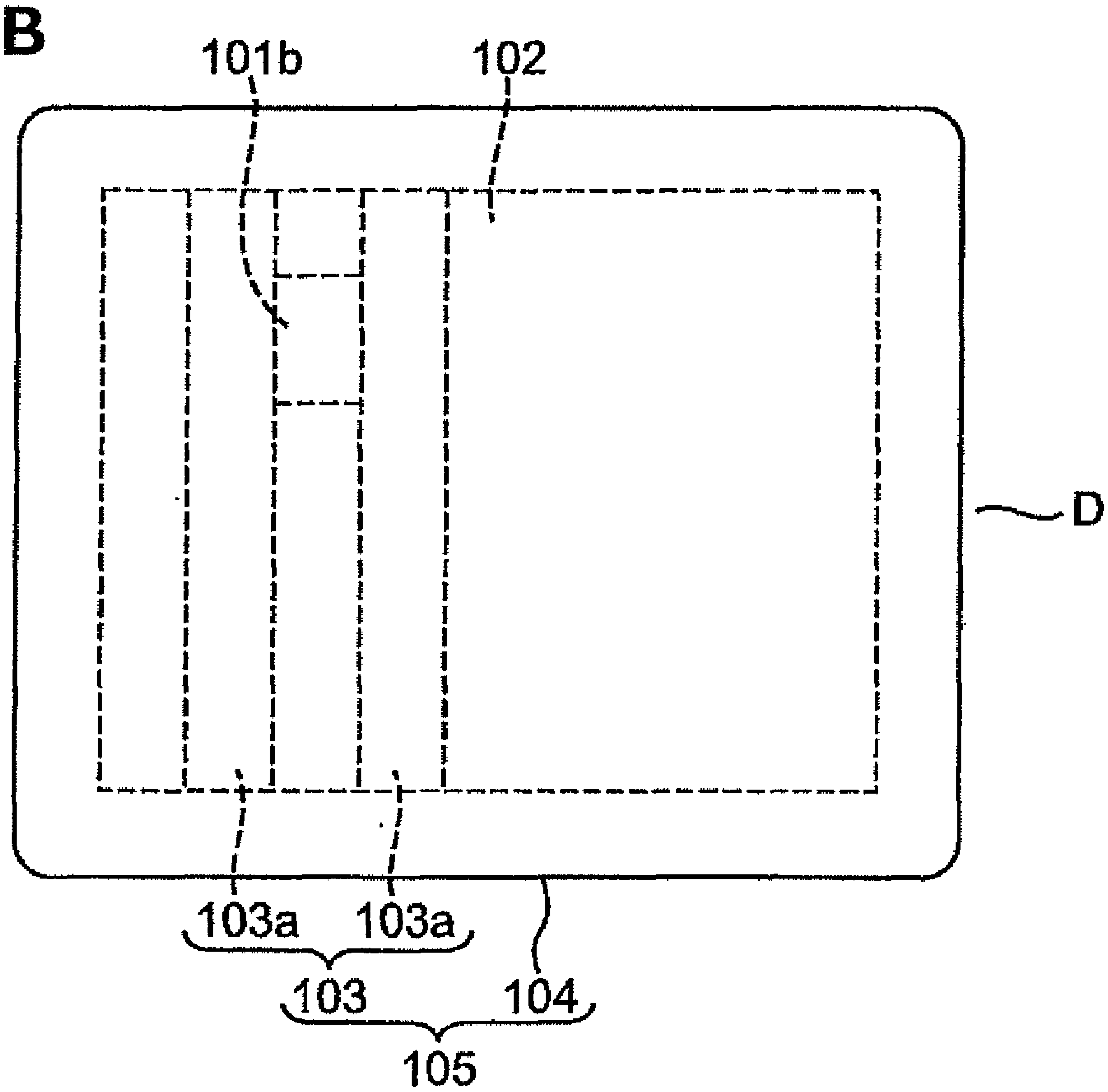


Fig.12A

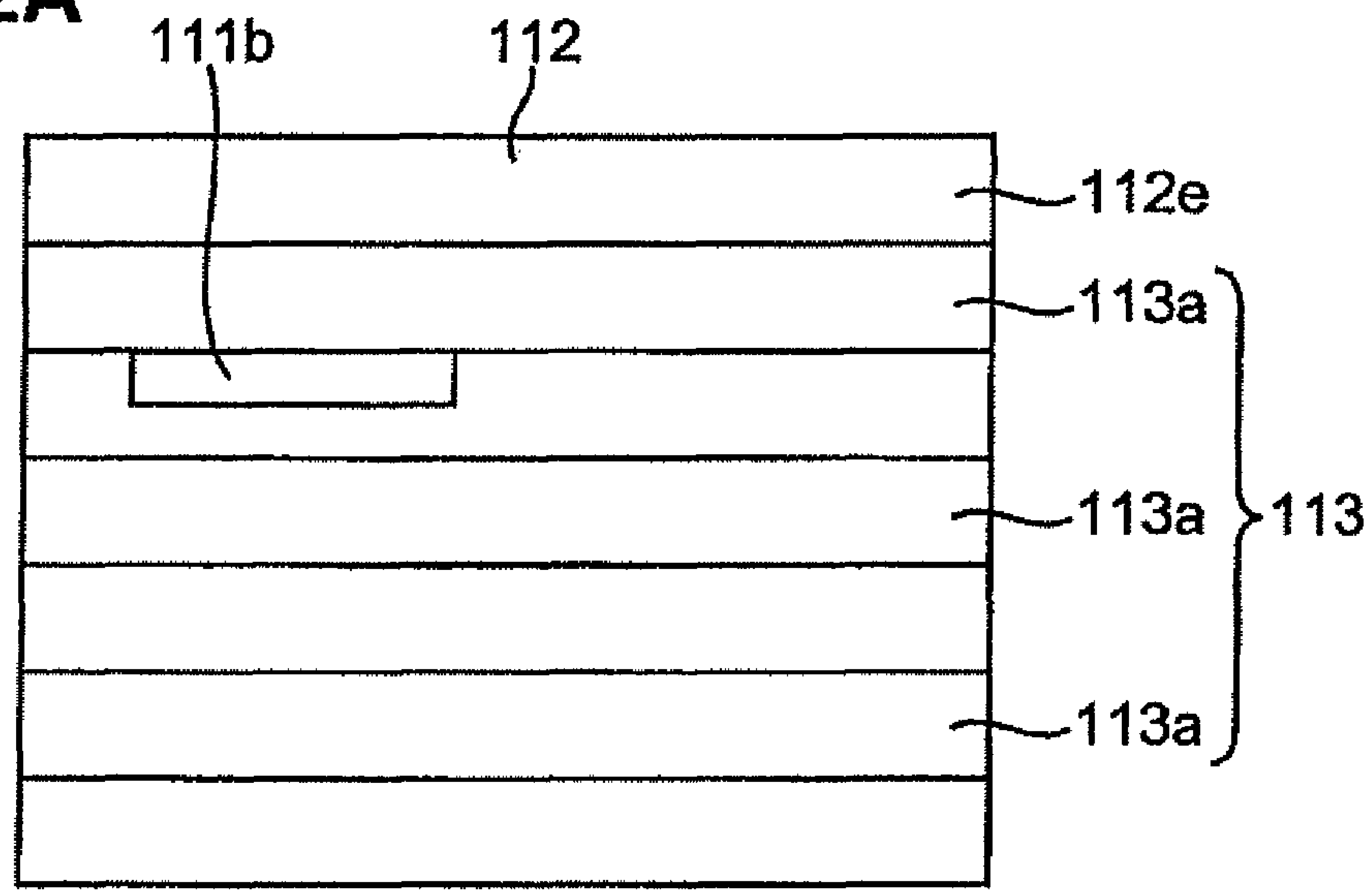


Fig.12B

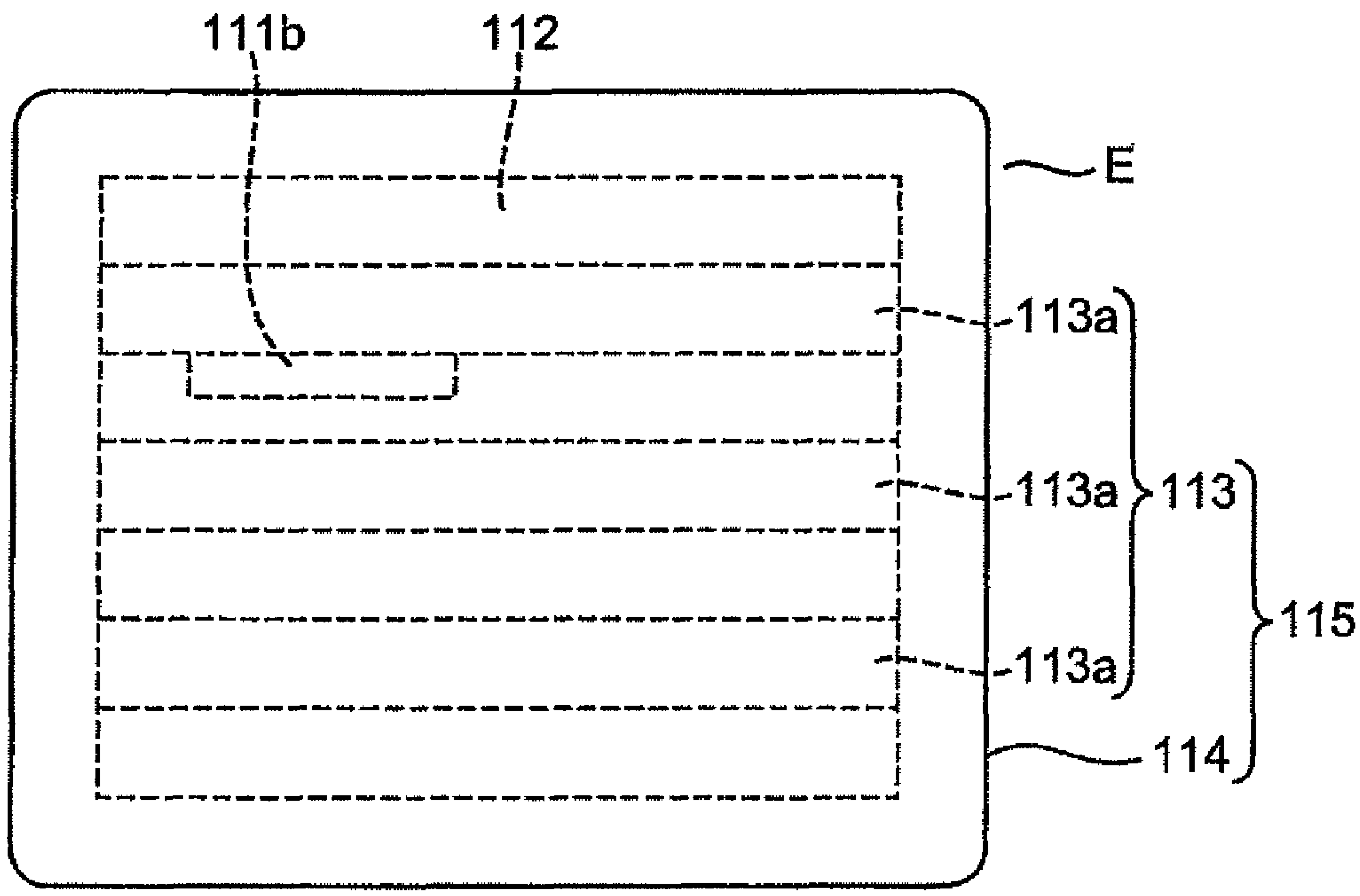


Fig.13A

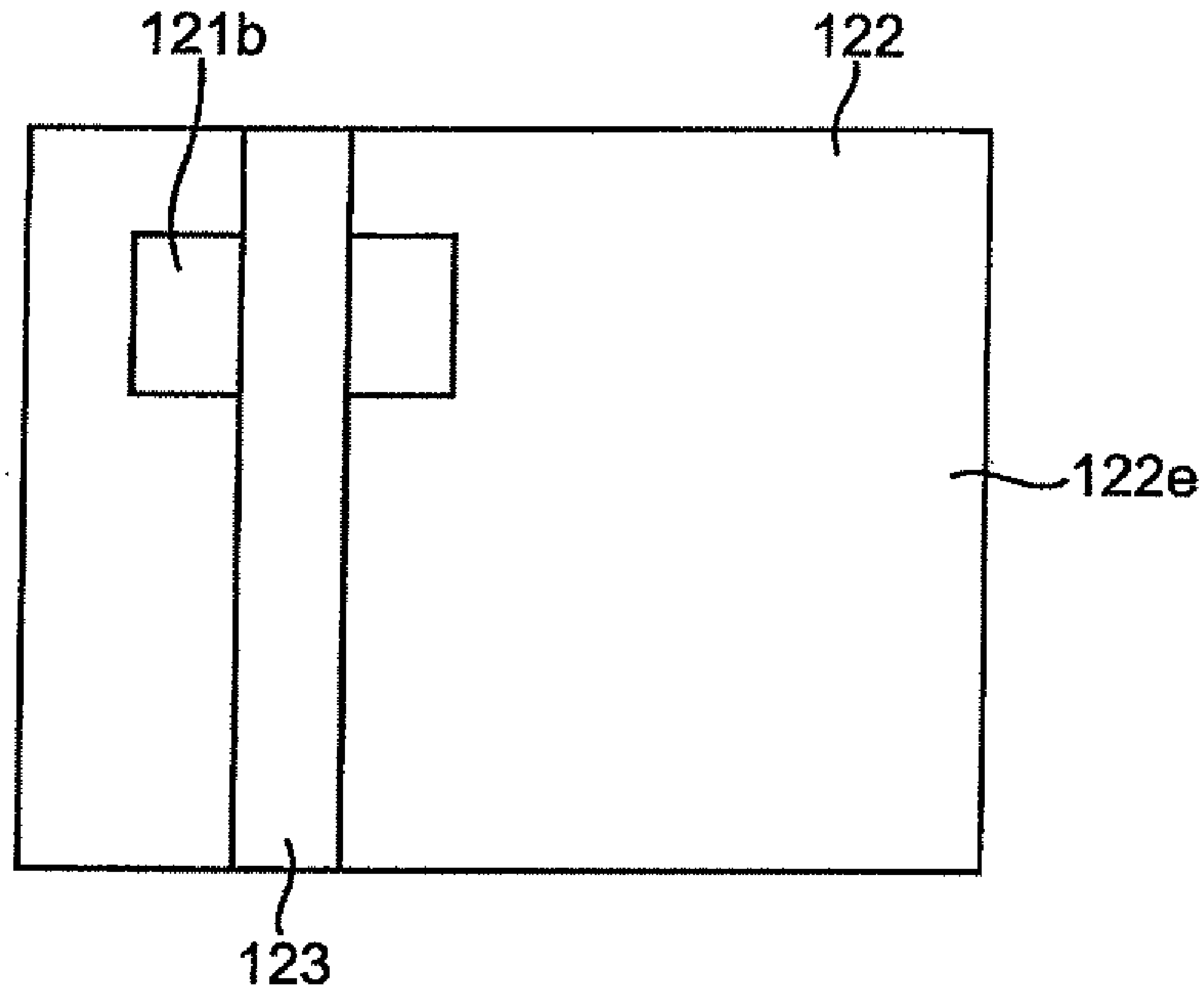


Fig.13B

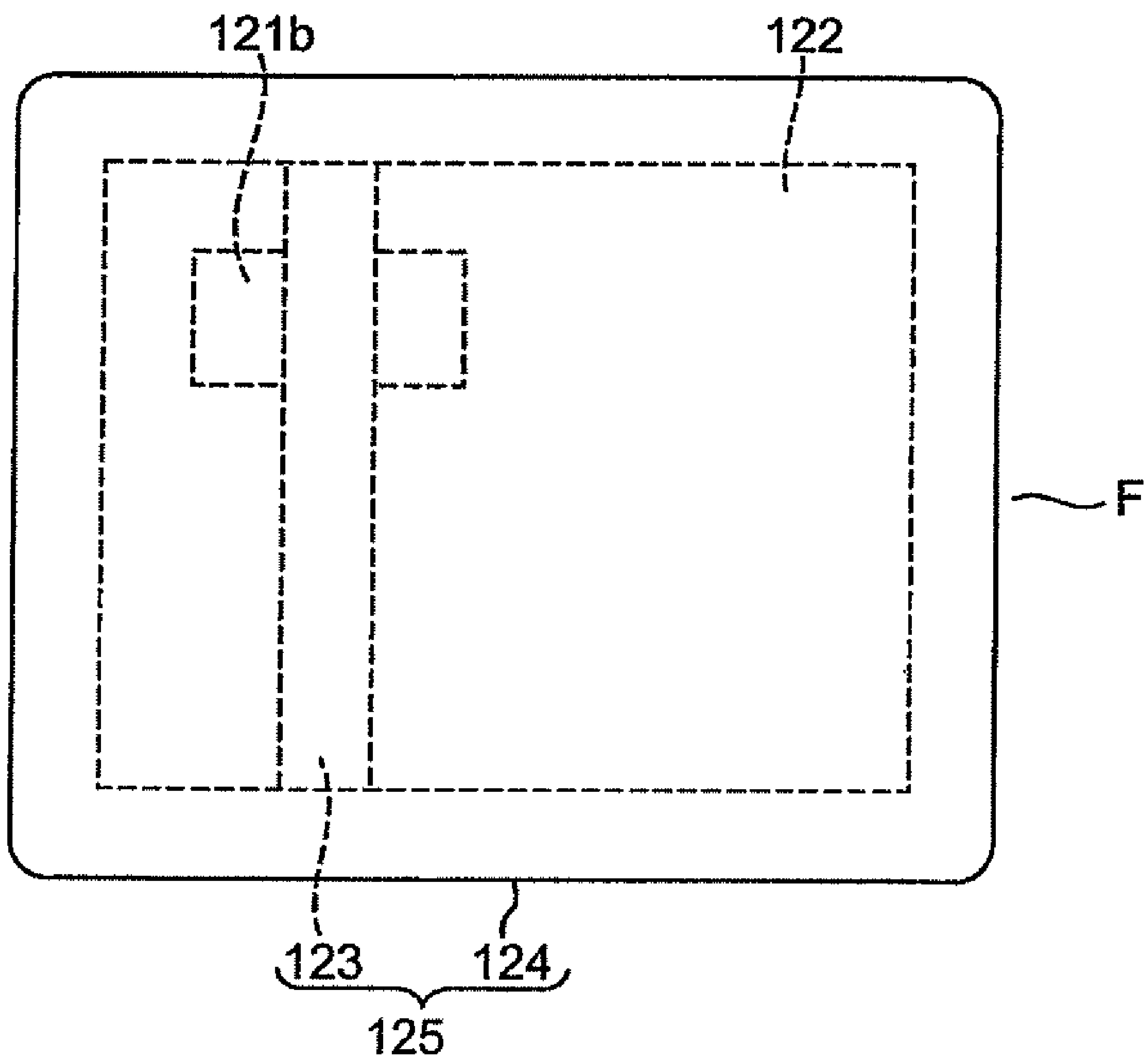


Fig.14

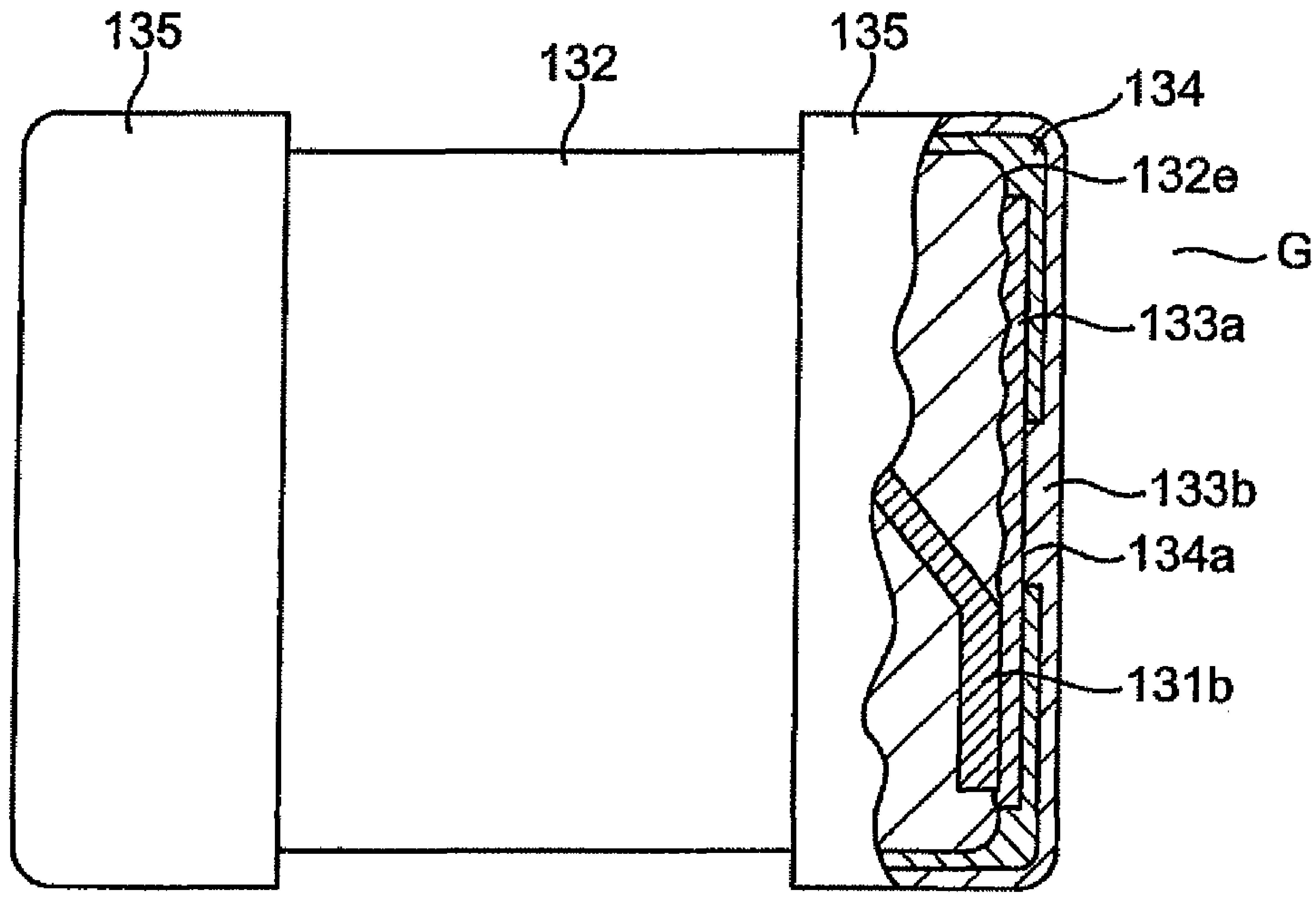

135
132
135
134
132e
G
133a
133b
134a
131b

Fig.15

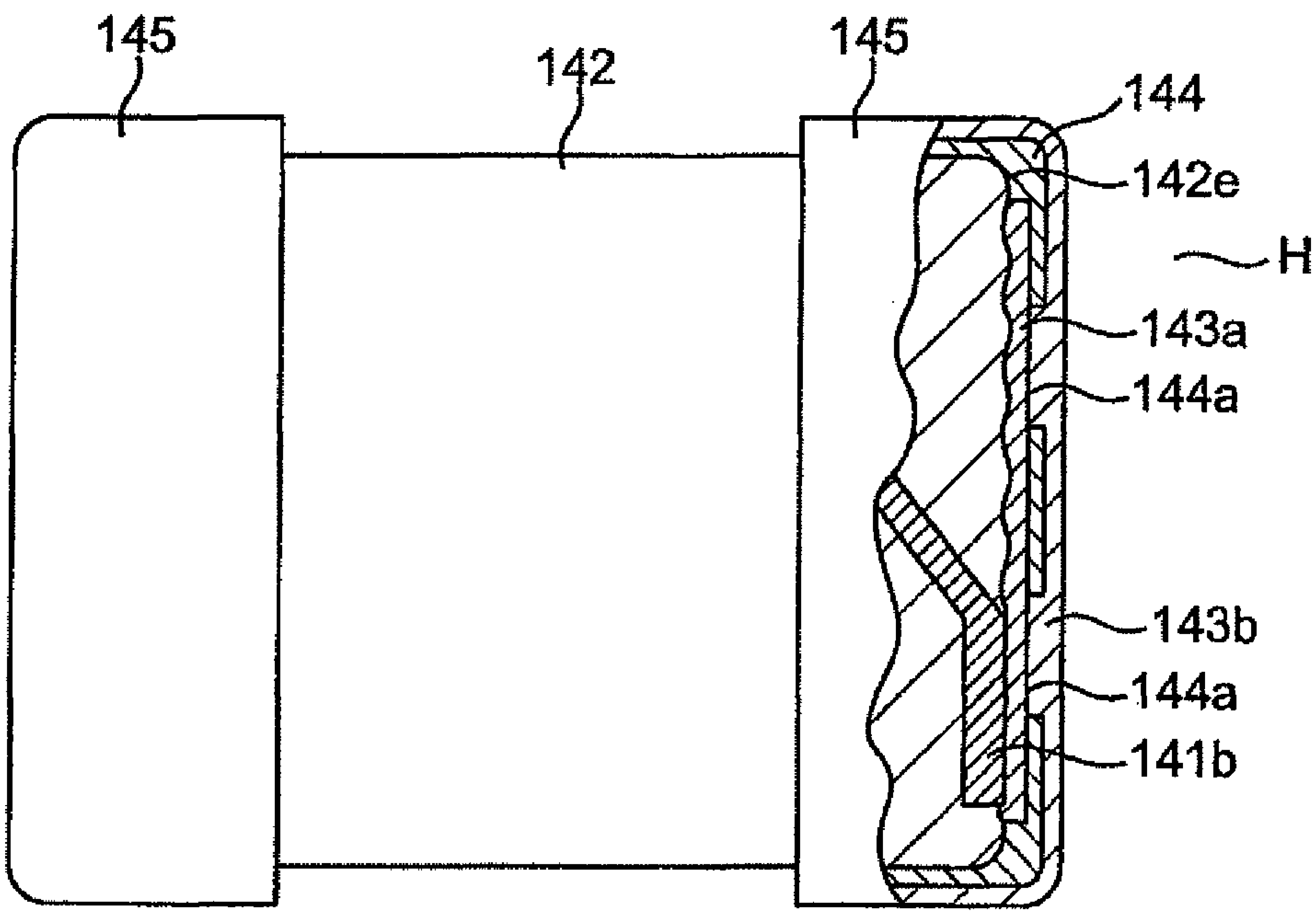

145
142
145
144
142e
H
143a
144a
143b
144a
141b

Fig.16

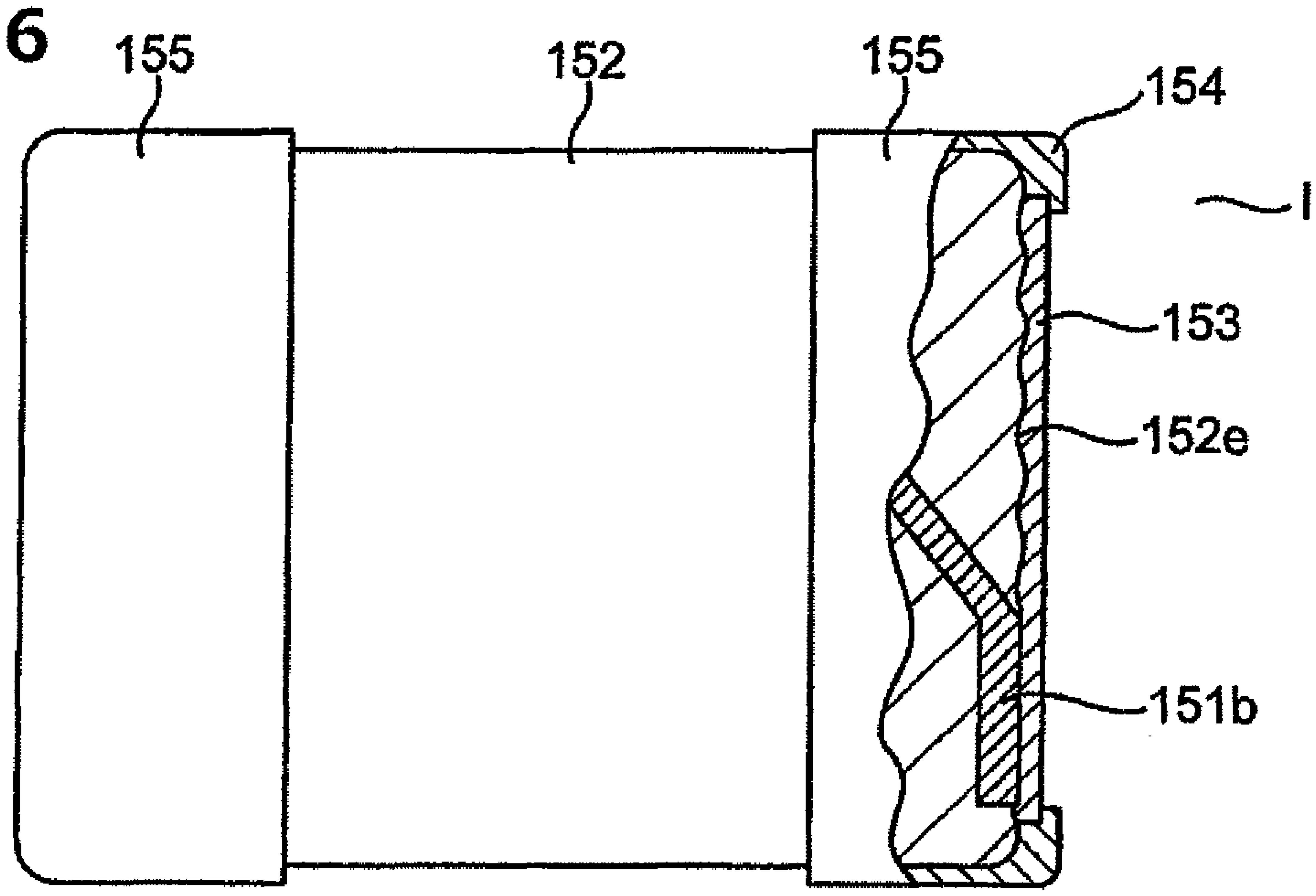

155
152
155
154
I
153
152e
151b

Fig.17

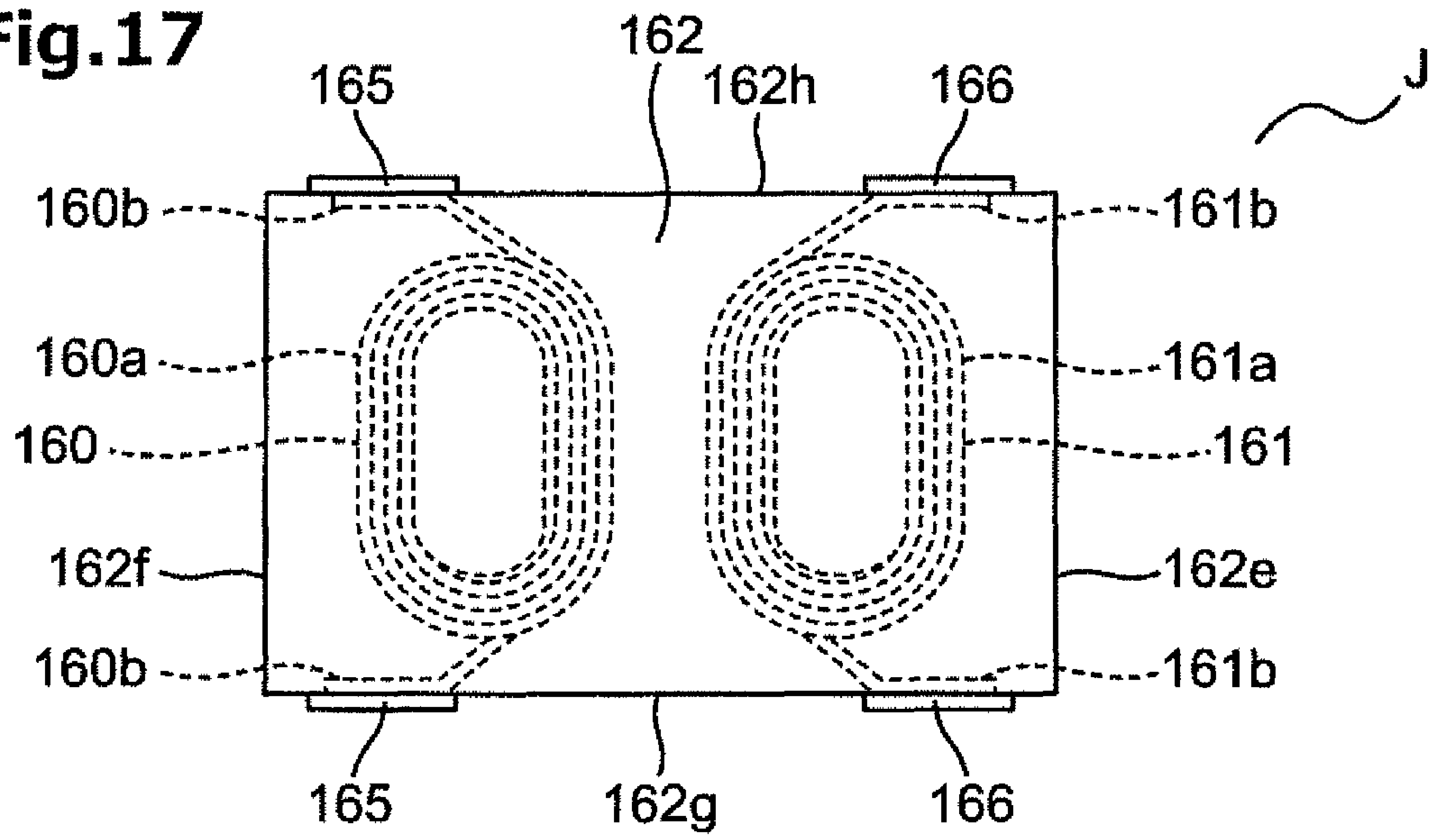

162
165
162h
166
J
160b
161b
160a
161a
160
161
162f
162e
160b
161b
165
162g
166

Fig.18

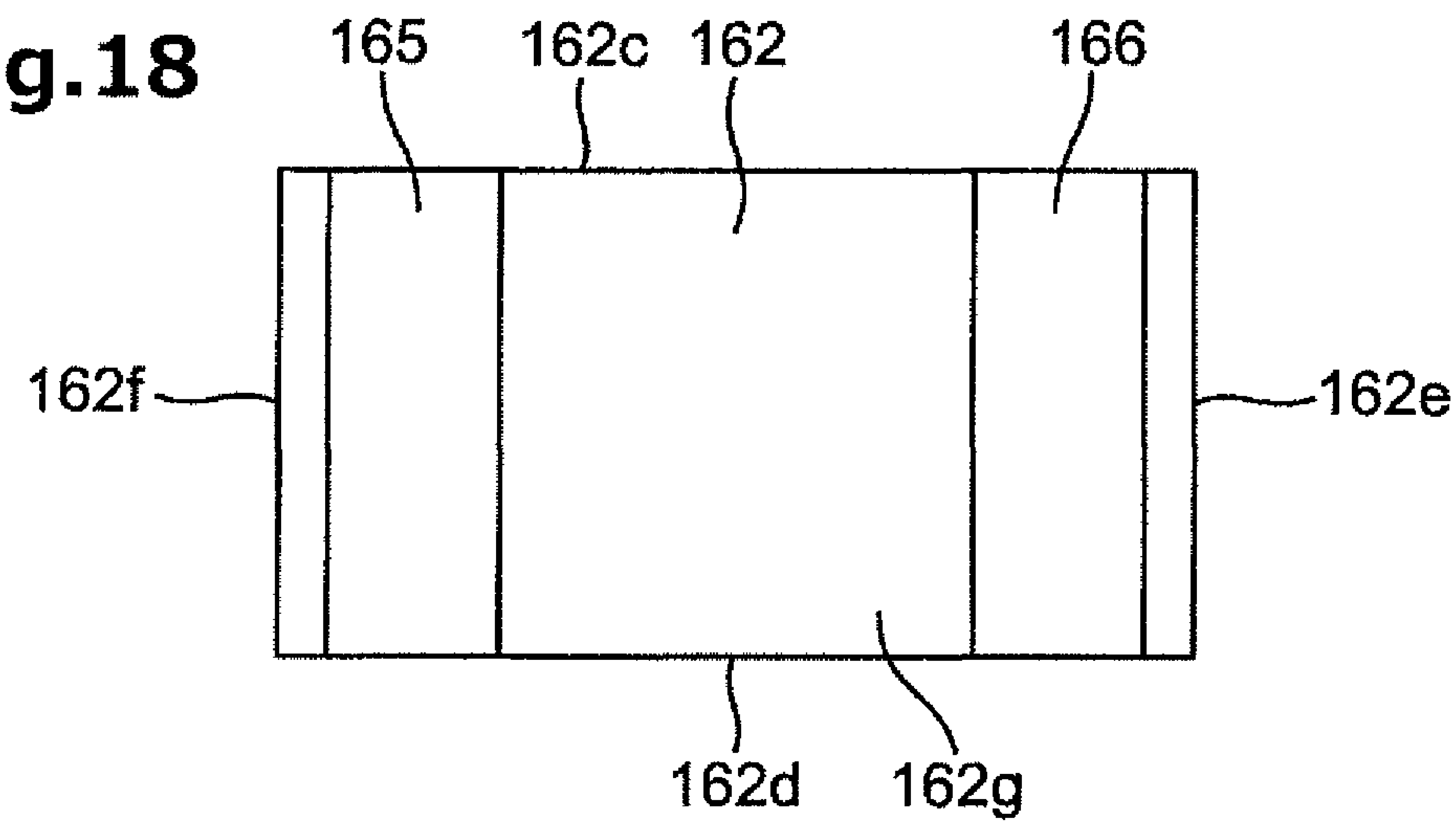


Fig.19

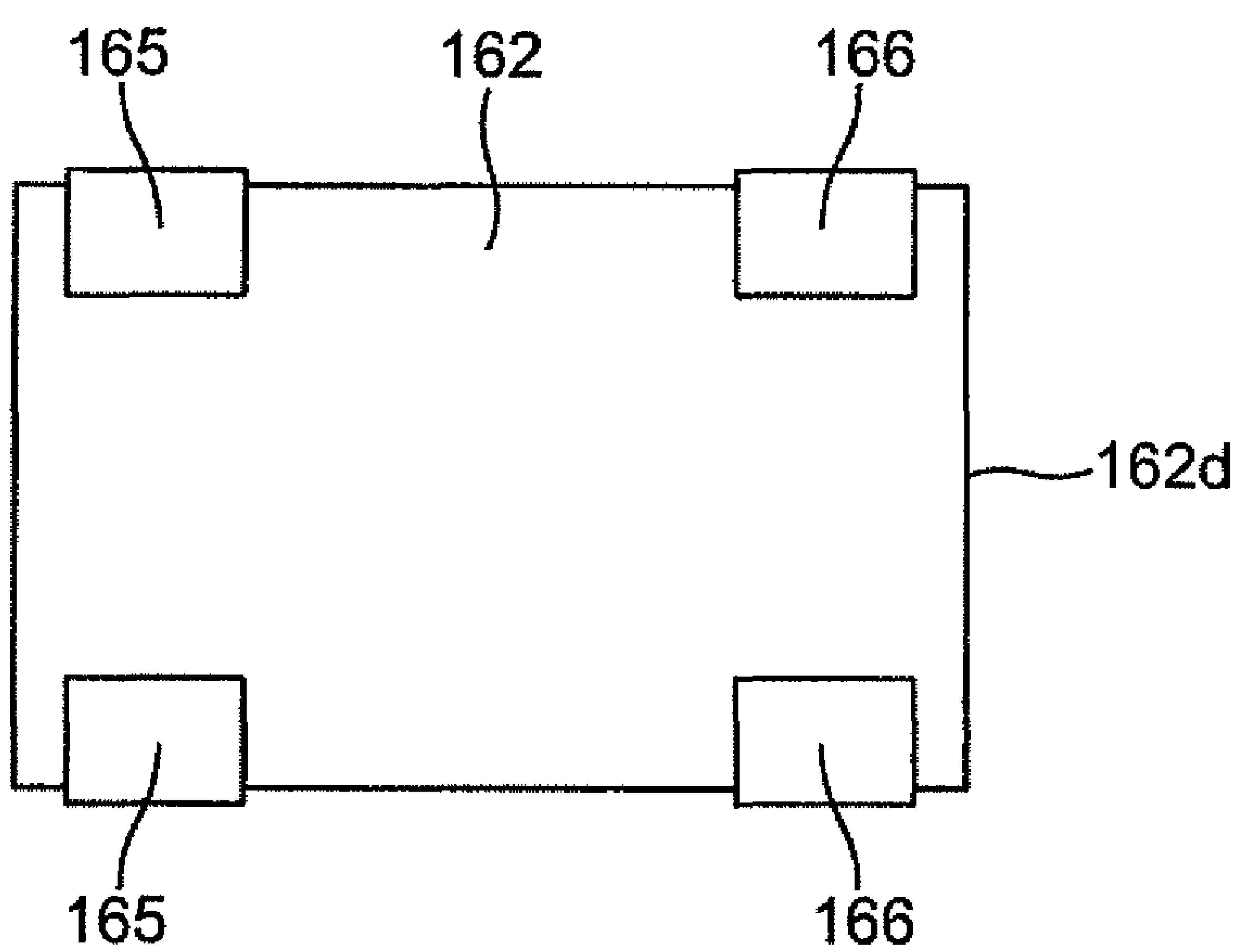
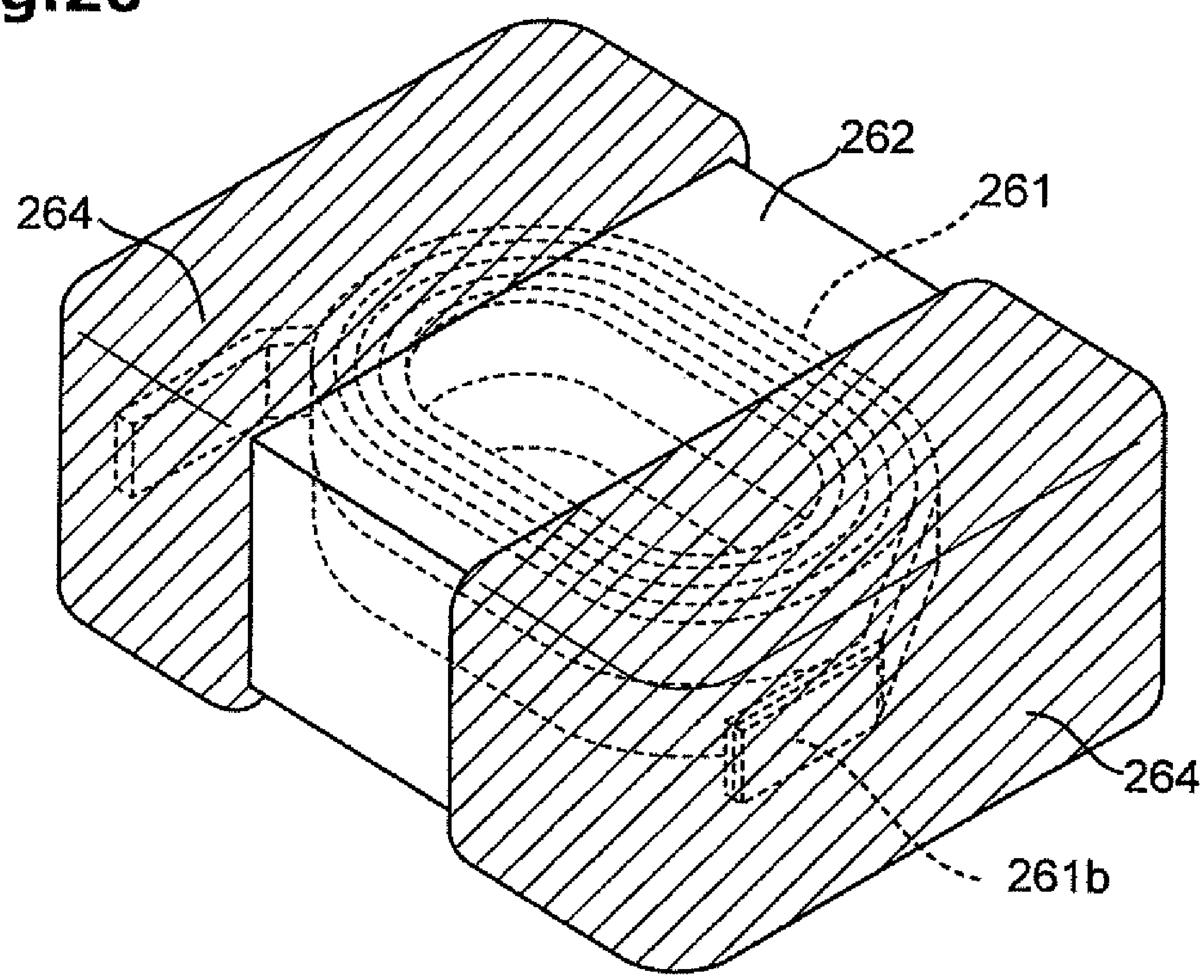


Fig.20



SURFACE-MOUNT INDUCTOR AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of priority to International Patent Application No. PCT/JP2016/085626, filed Nov. 30, 2016, and to Japanese Patent Application No. 2015-256012, filed Dec. 28, 2015, the entire contents of each are incorporated herein by reference.

BACKGROUND

Technical Field

The present disclosure relates to a surface-mount inductor and a manufacturing method thereof and, more particularly, to a surface-mount inductor having at least one coil buried in a molded body containing a metal magnetic powder and a manufacturing method thereof.

Background Art

For example, a conventional surface-mount inductor having a structure shown in FIG. **20** is known. The surface-mount inductor has a coil **261** formed by winding a conductive wire and buried in a molded body **262** formed of a sealing material containing a resin and a magnetic powder, and a pair of lead-out end parts **261***b*, **261***b* of the coil **261** is connected to a pair of external terminals **264**, **264** formed on the surface of the molded body **262**, as described, for example, in Japanese Laid-Open Patent Publication No. 2005-116708.

This surface-mount inductor is manufactured by forming the molded body **262** having the coil **261** built-in with a compression molding method or a powder compacting method and by applying a conductive paste to the molded body to form the external terminals **264**. The conductive paste used is a paste acquired by dispersing metal particles of Ag etc. in a thermosetting resin such as epoxy resin. This conductive paste is made conductive by bringing metal particles dispersed in the resin into contact with each other, or with a conductive wire, by utilizing a contraction stress due to curing of the thermosetting resin.

However, the conventional surface-mount inductor has a problem of high initial resistance and unstable bonding between a conductive wire and an external terminal due to weak bonding between the conductive wire and the external terminal. In this regard, it is proposed to form an external terminal by using a conductive paste containing metal fine particles with a particle diameter smaller than 100 nm as described, for example, in Japanese Laid-Open Patent Publication No. 2013-211333.

SUMMARY

A method using a conductive paste containing metal fine particles having a particle diameter smaller than 100 nm as in Japanese Laid-Open Patent Publication No. 2013-211333 can improve initial resistance of a bonding portion since the metal fine particles constituting the conductive paste are sintered at a low temperature. However, since a bonding strength between the molded body and the external terminal is weak, the method has a problem that the external terminal easily peels off from the molded body due to thermal shock. Furthermore, since the conductive paste containing metal

fine particles with minute particle diameter is expensive, the method also has a problem of increased manufacturing costs.

To solve such problems, the present inventor has proposed to remove the resin on the surface of the molded body to expose the metal magnetic powder on the surface of the molded body and to perform plating on a portion with the exposed metal magnetic powder so as to form an L-shaped external terminal (Japanese Patent Application No. 2014-180928).

However, the needs still exit for a surface-mount inductor having a stronger bonding strength between the molded body and the external terminal and a high connection reliability.

Therefore, the present disclosure provides a surface-mount inductor having external terminals with high connection reliability and a manufacturing method thereof.

A surface-mount inductor according to an embodiment of the present disclosure comprises a molded body containing a metal magnetic powder; at least one coil buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body; and an external terminal formed over an exposed surface of each of the lead-out end parts and a metal magnetic powder exposed portion formed at least around the exposed surface. The external terminal at least includes a first plating layer formed over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part and a conductive paste layer formed on the first plating layer and made of a solidified conductive paste.

Another aspect of the present disclosure provides a manufacturing method of a surface-mount inductor having at least one coil buried in a molded body containing a metal magnetic powder, the method comprising a molding step of placing the at least one coil in a molding die and filling a material for a molded body into the molding die to obtain the molded body, wherein the coil is buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body; and a step of forming an external terminal over an exposed surface of each of the lead-out end parts and a metal magnetic powder exposed portion formed at least around the exposed surface. The step of forming an external terminal at least includes a step of forming a first plating layer over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part and a step of forming a conductive paste layer made of a solidified conductive paste on the first plating layer.

According to the present disclosure, the surface-mount inductor having the external terminals with high connection reliability and the manufacturing method thereof can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a transparent schematic perspective view of a surface-mount inductor according to a first embodiment of the present disclosure;

FIG. **2** is a transparent schematic perspective view at a manufacturing step of the surface-mount inductor according to the first embodiment of the present disclosure;

FIG. **3** is a schematic perspective view at a manufacturing step of the surface-mount inductor according to the first embodiment of the present disclosure;

FIG. **4** is a schematic perspective view at a manufacturing step of the surface-mount inductor according to the first embodiment of the present disclosure;

FIG. **5** is a schematic perspective view of the surface-mount inductor according to the first embodiment of the present disclosure;

FIG. **6** is a partially cutaway schematic cross-sectional view of the surface-mount inductor according to the first embodiment of the present disclosure;

FIG. **7** is a schematic perspective view at a manufacturing step of a surface-mount inductor according to a second embodiment of the present disclosure;

FIG. **8** is a schematic perspective view at a manufacturing step of the surface-mount inductor according to the second embodiment of the present disclosure;

FIG. **9** is a schematic perspective view of the surface-mount inductor according to the second embodiment of the present disclosure;

FIG. **10**A is a schematic side view at a manufacturing step of a surface-mount inductor according to a third embodiment of the present disclosure;

FIG. **10**B is a transparent schematic side view of the surface-mount inductor according to the third embodiment of the present disclosure;

FIG. **11**A is a schematic side view at a manufacturing step of a surface-mount inductor according to a fourth embodiment of the present disclosure;

FIG. **11**B is a transparent schematic side view of the surface-mount inductor according to the fourth embodiment of the present disclosure;

FIG. **12**A is a schematic side view at a manufacturing step of a surface-mount inductor according to a fifth embodiment of the present disclosure;

FIG. **12**B is a transparent schematic side view of the surface-mount inductor according to the fifth embodiment of the present disclosure;

FIG. **13**A is a schematic side view at a manufacturing step of a surface-mount inductor according to a sixth embodiment of the present disclosure;

FIG. **13**B is a transparent schematic side view of the surface-mount inductor according to the sixth embodiment of the present disclosure;

FIG. **14** is a partially cutaway schematic cross-sectional view of a surface-mount inductor according to a seventh embodiment of the present disclosure;

FIG. **15** is a partially cutaway schematic cross-sectional view of a surface-mount inductor according to an eighth embodiment of the present disclosure;

FIG. **16** is a partially cutaway schematic cross-sectional view of a surface-mount inductor according to a ninth embodiment of the present disclosure;

FIG. **17** is a transparent schematic top view of a surface-mount inductor according to an eleventh embodiment of the present disclosure;

FIG. **18** is a schematic side view of the surface-mount inductor according to the eleventh embodiment of the present disclosure;

FIG. **19** is a schematic bottom view of the surface-mount inductor according to the eleventh embodiment of the present disclosure; and

FIG. **20** is a transparent schematic perspective view of a conventional surface-mount inductor.

DETAILED DESCRIPTION

Embodiments of the present disclosure will now be described with reference to the drawings etc. In the following drawings, the same members used are denoted by the same reference numerals and will not repeatedly be described or will be described in a simplified manner in some cases.

First Embodiment

A surface-mount inductor according to this embodiment is characterized by comprising a molded body containing a metal magnetic powder, at least one coil buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body, and an external terminal formed over an exposed surface of each of the lead-out end parts and a metal magnetic powder exposed portion formed at least around the exposed surface. The external terminal at least includes a first plating layer formed over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part and a conductive paste layer formed on the first plating layer and made of a solidified conductive paste.

An example of a structure of a surface-mount inductor A according to this embodiment will be described with reference to FIGS. **1** and **2**. FIG. **1** is a transparent schematic perspective view of a structure inside the surface-mount inductor A. The surface-mount inductor A has a molded body **12** having a substantially rectangular parallelepiped shape and external terminals **15**, **15** formed at both ends thereof. The molded body **12** has an upper surface **12***c* and a bottom surface **12***d* opposite to each other and four side surfaces **12***e*, **12***f*, **12***g*, **12***h* adjacent to the upper surface **12***c* and the bottom surface **12***d*. FIG. **2** is a transparent schematic perspective view of a structure of the molded body **12**, showing a state before forming the external terminals of FIG. **1**. One coil **11** formed by winding a conductive wire is buried in the molded body **12**. The coil **11** is a coil including a winding part **11***a* formed by a so-called "outside-to-outside winding" in which a conductive wire is wound such that both ends are arranged in directions opposite to each other along an outer circumferential surface of the coil, and a pair of lead-out end parts **11***b*, **11***b* disposed at both ends of the winding part **11***a* and made up of non-winding portions. FIG. **2** shows an example of two-tier outside-to-outside winding. The paired lead-out end parts **11***b*, **11***b* of the coil **11** are respectively exposed on the first side surface **12***e* and the second side surface **12***f* opposite to each other arranged in the length direction of the molded body **12**. A plating layer described later is formed entirely on each of the first side surface **12***e* and the second side surface **12***f* including the exposed surfaces of the lead-out end parts **11***b*, **11***b*. Additionally, on the plating layers, a pair of conductive paste layers **14**, **14** made of a solidified conductive paste is formed to cover five surfaces at both ends of the molded body **12**, or in other words, to cover the five surfaces at one end, i.e., the first side surface **12***e* as well as the upper surface **12***c*, the bottom surface **12***d*, and the third side surface **12***g* and the fourth side surface **12***h* opposite to each other, which are in direct contact with the first side surface **12***e*, and cover the five surfaces at the other end, i.e., the second side surface **12***f* as well as the upper surface **12***c*, the bottom surface **12***d*, and the third side surface **12***g* and the fourth side surface **12***h* opposite to each other, which are in direct contact with the second side surface **12***f*. The lead-out end parts **11***b*, **11***b* at both ends of the coil **11** are respectively connected to the pair of the conductive paste layers **14**, **14** via the plating layers. The plating layers and the conductive paste layers constitute the external terminals **15**, **15**. The first and second side surfaces opposite to each other in the molded body mean opposite side surfaces with which a straight line connecting the lead-out end parts at both ends of the coil intersects. In FIG. **2**, the side surfaces correspond to the first side surface **12***e* and second side surface **12***f* opposite to each other arranged in the length direction of the molded body **12**.

In FIG. **2**, a coil having an elliptical shape in a top view is shown; however, the coil is not limited thereto and may have a circular shape or a substantially rectangular shape in a top view. Although the lead-out end parts **11***b*, **11***b* are respectively exposed on the first side surface **12***e* and the second side surface **12***f*, the exposed area is not particularly limited as long as electric connection to the external terminals can be formed. The lead-out end parts may project from the first side surface and the second side surface to the extent that the formation of the plating layers formed thereon is not hindered.

The molded body contains the metal magnetic powder and a binder resin as well as additives such as a moldability improving agent and a releasing agent as needed. Examples of the metal magnetic powder can include iron-based metal magnetic powders of Fe, Fe—Si—Cr, Fe—Si—Al, Fe—Ni—Al, Fe—Cr—Al, etc., metal magnetic powders of amorphous etc., metal magnetic material powders with surfaces covered with an insulator such as glass, and metal magnetic material powders with modified surfaces. Examples of the binder resin can include thermosetting resins such as epoxy resin, polyimide resin, and phenol resin, and thermoplastic resins such as polyethylene resin and polyamide resin. Although FIG. **2** shows the case of the molded body having a rectangular parallelepiped shape, the molded body may have another rectangular shape, for example, a cube shape.

The surface-mount inductor A can be manufactured by using the following manufacturing method, for example. Specifically, the manufacturing method is a manufacturing method of a surface-mount inductor having at least one coil buried in a molded body containing a metal magnetic powder and comprises a molding step of placing the at least one coil in a molding die and filling a material for a molded body into the molding die to obtain the molded body, with the coil being buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body. The manufacturing method further comprises a step of forming an external terminal over an exposed surface of each of the lead-out end parts and a metal magnetic powder exposed portion formed at least around the exposed surface. The step of forming an external terminal at least includes a step of forming a first plating layer over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part, and a step of forming a conductive paste layer made of a solidified conductive paste on the first plating layer. The manufacturing method will hereinafter be described with reference to FIGS. **1** to **5**.

(Molding Step)

This step is a molding step of placing at least one coil in a molding die and filling a material for a molded body into the molding die to obtain the molded body having a rectangular parallelepiped shape with upper and bottom surfaces opposite to each other and four side surfaces, and the coil is buried in the molded body such that the lead-out end parts at both ends of the coil are at least partially exposed respectively on first and second side surfaces opposite to each other.

First, after the winding part **11***a* is formed by spirally winding a conductive wire having a rectangular cross section with insulating coating in outside-to-outside manner in two tiers such that both ends thereof are located on the outer circumference, both ends of the conductive wire are led out from the outer circumference of the winding part in the opposite directions to form the lead-out end parts **11***b*, **11***b* at both ends so that the coil **11** is formed. A resin used for the insulating coating is preferably a resin having a high heat resistance temperature and may be a polyamide-based resin, a polyester-based resin, an imide-modified polyurethane resin, etc. The conductive wire may be not only a rectangular conductive wire having a rectangular cross section but also a round wire or a wire having a polygonal cross section.

Subsequently, by using a magnetic material, for example, an iron-based metal magnetic powder of Fe, Fe—Si—Cr, Fe—Si—Al, Fe—Ni—Al, Fe—Cr—Al, etc. or a metal magnetic powder of amorphous etc., and a binder resin, for example, an epoxy resin, a sealing material (material for a molded body) is manufactured by granulating a mixture thereof into a powdered state. The coil **11** is then placed in a predetermined molding die, and the material for a molded body is filled in the mold and is subjected to compression molding. By placing the coil in the die such that the lead-out end parts at both ends of the coil are at least partially exposed respectively on the first and second side surfaces opposite to each other on the molded body, the molded body **12** can be molded such that the lead-out end parts at both ends of the coil are at least partially exposed respectively on the first and second side surfaces opposite to each other on the molded body. The molding method is not limited to the compression molding method, and a powder compacting method is also usable.

(Step of Forming Metal Magnetic Powder Exposed Portion and External Terminal)

Films on the surfaces of the lead-out end parts **11***b*, **11***b* at both ends of the coil **11** are removed by mechanical peeling. Subsequently, as shown in FIG. **3**, resin components present on the surfaces of the first side surface **12***e* and the second side surface **12***f* opposite to each other on the molded body **12** are removed by using laser irradiation, blasting treatment, polishing, etc. As a result, on the first side surface **12***e* and the second side surface **12***f* other than the exposed surfaces of the lead-out end parts **11***b*, **11***b* at both ends, a metal magnetic powder exposed portion **12***b* is formed such that the metal magnetic powder constituting the molded body **12** is exposed. FIG. **3** shows an example of the metal magnetic powder exposed portion **12***b* formed entirely on the first side surface **12***e* and the second side surface **12***f*; however, the metal magnetic material powder exposed portion **12***b* may be formed at least around the exposed surfaces of the lead-out end parts **11***b*, **11***b* at both ends.

Subsequently, a plating process is performed on the exposed surfaces of the lead-out end parts **11***b*, **11***b* at both ends and the metal magnetic powder exposed portion **12***b* to form a plating layer **13** as shown in FIG. **4**. The plating layer **13** is formed entirely over the first side surface **12***e* and the second side surface **12***f*. As a result, the lead-out end parts **11***b*, **11***b* are connected to the plating layer **13**. A conductive material used for the plating process is not particularly limited as long as the material is a metal usable for plating. For example, a material containing at least one metal material selected from the group consisting of Cu, Ni, and Sn can be used.

Subsequently, a conductive paste is applied over the first side surface **12***e* and the four surfaces adjacent to the first side surface **12***e*, i.e., the upper surface **12***c*, the bottom surface **12***d*, the third side surface **12***g*, and the fourth side surface **12***h*. The conductive paste is also applied over the second side surface **12***f* and the four surfaces adjacent to the second side surface **12***f*, i.e., the upper surface **12***c*, the bottom surface **12**_d_, the third side surface **12**_e_, and the fourth side surface **12**_f_. Subsequently, a heat treatment is performed to dry and solidify the conductive paste to form the conductive paste layers **14**, **14**, so that the external terminals **15**, **15** are formed. As a result, the surface-mount inductor A shown in the schematic perspective view of FIG. **5** is obtained. The conductive paste can be a paste acquired by dispersing metal particles of Au, Ag, etc. in a thermosetting resin such as an epoxy resin.

FIG. **6** is a partially cutaway schematic cross-sectional view of the obtained surface-mount inductor A. The surface of the lead-out end part **11**_b_ is exposed on the first side surface **12**_e_. The plating layer **13** is formed to cover the surface of the lead-out end part **11**_b_ and the metal magnetic material powder exposed portion **12**_b_. The plating layer **13** is further covered with the conductive paste layer **14**. The external terminal **15** is made up of the plating layer **13** and the conductive paste layer **14**.

According to this embodiment, since the metal magnetic material powder exposed portion is formed at least around the exposed surface of the lead-out end part of the coil, the plating is facilitated on the metal magnetic material powder exposed portion, so that the lead-out end part and the plating layer can firmly be bonded. Additionally, since the bonding area between the conductive paste layer and the lead-out end part can be increased via the plating layer, the bonding strength can be increased not only between the lead-out end part and the external terminal but also between the molded body and the external terminal, so that the external terminal can be prevented from peeling off due to thermal shock or physical stress. Therefore, the surface-mount inductor having the external terminals with high connection reliability can be provided. Moreover, when the external terminals are formed, the metal magnetic powder may be exposed only on the side surfaces on which the lead-out end parts of the coil are exposed, so that the workability of the external terminals can be improved as compared to a method in which the metal magnetic powder on another surface must be exposed, for example, when the external terminals are L-shaped.

Second Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except that the metal magnetic powder is exposed only around the exposed surfaces of the lead-out end parts on the side surfaces on which the lead-out end parts of the coil are exposed. Description will be made with reference to FIGS. **7** to **9**, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **7** is a schematic perspective view at a manufacturing step of a surface-mount inductor B according to this embodiment. FIG. **8** is a schematic perspective view at a manufacturing step of the surface-mount inductor B. FIG. **9** is a schematic perspective view of the surface-mount inductor B.

As shown in FIG. **7**, a molded body **62** has an upper surface **62**_c_ and a bottom surface **62**_d_ opposite to each other and four side surfaces **62**_e_, **62**_f_, **62**_g_, **62**_h_ in direct contact with the upper surface **62**_c_ and the bottom surface **62**_d_. The first side surface **62**_e_ and the second side surface **62**_f_ are side surfaces opposite in the length direction of the molded body **62** and have lead-out end parts **61**_b_, **61**_b_ at both ends of the coil **61** exposed thereon. Metal magnetic powder exposed portions **62**_b_, **62**_b_ are formed around the exposed surfaces of the lead-out end parts **61**_b_, **61**_b_ at both ends.

As shown in FIG. **8**, a plating layer **63** is formed over the exposed surface of the lead-out end part **61**_b_ of the coil **61** and the metal magnetic powder exposed portion **62**_b_. As shown in FIG. **9**, a conductive paste layer is formed into an L shape over the first side surface **62**_e_ and the bottom surface **62**_d_ to form an external terminal **65**. A conductive paste layer is formed into an L shape over the second side surface **62**_f_ and the bottom surface **62**_d_ to form an external terminal **65**. As a result, the lead-out end **61**_b_ and the external terminal **65** are connected.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, since the resin components may be removed only around the exposed surfaces of the lead-out end parts, the workability of the external terminals can further be improved.

Third Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except using a plating layer having a mesh structure. Description will be made with reference to FIGS. **10**A to **10**B, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **10**A is a schematic side view at a manufacturing step of a surface-mount inductor C according to this embodiment, showing a state before forming external terminals. FIG. **10**B is a transparent schematic side view of the surface-mount inductor C.

As shown in FIG. **10**A, a lead-out end part **91**_b_ is exposed on a first side surface **92**_e_ of a molded body **92**. A plating layer **93** having a mesh structure is formed entirely on the first side surface **92**_e_. As shown in FIG. **10**B, a conductive paste layer **94** is formed to cover the plating layer **93**. The conductive paste layer **94** is formed over the first side surface **92**_e_ and four surfaces adjacent to the first side surface **92**_e_. As a result, the conductive paste layer **94** is bonded via the plating layer **93** to the lead-out end part **91**_b_. The plating layer **93** having a mesh structure can be formed by removing the resin component on the surface of the first side surface **92**_e_ in a mesh shape by laser irradiation to form a metal magnetic material powder exposed portion having a mesh structure before performing a plating process. Although not shown, a plating layer having a mesh structure is also formed entirely on a second side surface opposite to the first side surface **92**_e_, and a conductive paste layer is further formed on the plating layer over the second side surface and four surfaces adjacent to the second side surface.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, the bonding strength between the molded body **92** and the external terminals **95** can further be improved by the anchor effect of the conductive paste **94** having entered gaps of the mesh structure of the plating layer **93**.

Fourth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except using a plating layer having a slit structure. Description will be made with reference to FIGS. **11**A to **11**B, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **11**A is a schematic side view at a manufacturing step of a surface-mount inductor D according to this embodiment, showing a state before forming external terminals. FIG. **11**B is a transparent schematic side view of the surface-mount inductor D.

As shown in FIG. **11**A, a lead-out end part **101***b* is exposed on a first side surface **102***e* of a molded body **102**. A plating layer **103** having a slit structure is formed entirely on the first side surface **102***e*. As shown in FIG. **11**B, a conductive paste layer **104** is formed to cover the plating layer **103**. The conductive paste layer **104** is formed over the first side surface **102***e* and four surfaces adjacent to the first side surface **102***e*. As a result, the conductive paste layer **104** is bonded via the plating layer **103** to the lead-out end part **101***b*. Regarding the plating layer **103** having a slit structure, the resin component on the surface of the first side surface **102***e* can be removed in a slit shape by laser irradiation to form multiple projecting metal magnetic material powder exposed portions extending in the lateral direction of the first side surface **102***e* before performing a plating process so as to form the plating layer **103** having multiple projecting platings **103***a* arranged in the lateral direction of the first side surface **102***e*. Although not shown, a plating layer having a slit structure is also formed entirely on a second side surface opposite to the first side surface **102***e*, and an external terminal is further formed on the plating layer over the second side surface and four surfaces adjacent to the second side surface.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, the bonding strength between the molded body **102** and the external terminals **105** can further be improved by the anchor effect of the conductive paste having entered gaps of the slit structure of the plating layer **103**.

Fifth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except using a plating layer having a slit structure. Description will be made with reference to FIGS. **12**A to **12**B, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **12**A is a schematic side view at a manufacturing step of a surface-mount inductor E according to this embodiment, showing a state before forming external terminals. FIG. **12**B is a transparent schematic side view of the surface-mount inductor E.

As shown in FIG. **12**A, a lead-out end part **111***b* is exposed on a first side surface **112***e* of a molded body **112**. A plating layer **113** having a slit structure is formed entirely on the first side surface **112***e*. As shown in FIG. **12**B, a conductive paste layer **114** is formed to cover the plating layer **113**. The conductive paste layer **114** is formed over the first side surface **112***e* and four surfaces adjacent to the first side surface **112***e*. As a result, the conductive paste layer **114** is bonded via the plating layer **113** to the lead-out end part **111***b*. Regarding the plating layer **113** having a slit structure, the resin component on the surface of the first side surface **112***e* can be removed in a slit shape by laser irradiation to form multiple projecting metal magnetic material powder exposed portions extending in the lateral direction of the first side surface **112***e* before performing a plating process so as to form the plating layer **113** having multiple belt-shaped plating layers **113***a* arranged in the longitudinal direction of the first side surface **112***e*. Although not shown, a plating layer having a slit structure is also formed entirely on a second side surface opposite to the first side surface **112***e*, and a conductive paste layer is further formed on the plating layer over the second side surface and four surfaces adjacent to the second side surface.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, the bonding strength between the molded body **112** and the external terminals **115** can further be improved by the anchor effect of the conductive paste **114** having entered gaps of the slit structure of the plating layer **113**.

Sixth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except that plating layers are formed in the longitudinal direction of a first side surface and a second side surface to at least partially overlap with exposed surfaces of lead-out end parts. Description will be made with reference to FIGS. **13**A to **13**B, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **13**A is a schematic side view at a manufacturing step of a surface-mount inductor F according to this embodiment, showing a state before forming external terminals. FIG. **13**B is a transparent schematic side view of the surface-mount inductor F.

As shown in FIG. **13**A, a lead-out end part **121***b* is exposed on a first side surface **122***e* of a molded body **122**. A plating layer **123** is formed in the longitudinal direction of the first side surface **122***e* to overlap with a substantially central portion of an exposed surface of the lead-out end part **121***b*. As shown in FIG. **13**B, a conductive paste layer **124** is formed to cover the plating layer **123**. The conductive paste layer **124** is formed over the first side surface **122***e* and four surfaces adjacent to the first side surface **122***e*. As a result, the conductive paste layer **124** is bonded via the plating layer **123** to the lead-out end part **121***b*. Although not shown, a plating layer is also formed on a second side surface opposite to the first side surface **112***e* in the longitudinal direction of the second side surface to overlap with a substantially central portion of an exposed surface of a lead-out end part, and an external terminal is further formed on the plating layer over the second side surface and four surfaces adjacent to the second side surface. Although FIGS. **13**A and **13**B show an example of the plating layer **123** formed in the longitudinal direction of the first side surface **122***e* to overlap with the substantially central portion of the exposed surface of the lead-out end part **121***b*, the plating layer **123** may overlap at least partially with the exposed surface of the lead-out end part **121***b*.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, the bonding strength between the plating layers and the lead-out end parts can be improved by forming the plating layers directly on the exposed surfaces of the lead-out end parts.

Seventh Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except that an external terminal includes a first plating layer, a conductive paste layer, and a second plating layer formed on the conductive paste layer while the conductive layer has a conductive-paste-layer non-formation region with the first plating layer and the second plating layer directly bonded in the conductive-paste-layer non-formation region. Description will be made with reference to FIG. **14**, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **14** is a partially cutaway schematic cross-sectional view of a surface-mount inductor G according to this embodiment. A lead-out end part **131***b* is exposed on a first side surface **132***e* of a molded body **132**. An external terminal **135** includes a first plating layer **133***a*, a conductive paste layer **134**, and a second plating layer **133***b*. The first plating layer **133***a* is formed on the lead-out end part **131***b*, the conductive paste layer **134** having one conductive-paste-layer non-formation region **134***a* is formed on the first plating layer **133***a*, and the second plating layer **133***b* is formed on the conductive paste layer **134** to cover the conductive paste layer **134**. The first plating layer **133***a* and the second plating layer **133***b* are directly bonded in the conductive-paste-layer non-formation region **134***a* disposed in a substantially central portion of the first plating layer **133***a*. The first plating layer **133***a* is formed entirely on the first side surface **132***e*. The conductive paste layer **134** is formed over the first side surface **132***e* and four surfaces adjacent to the first side surface **132***e*. Although a metal material such as Cu, Ni, and Sn can be used for the plating layer, it is preferable to use Cu for the first plating layer and Ni for the second plating layer. Although not shown, also on a second side surface opposite to the first side surface **132***e*, an external terminal includes a first plating layer, a conductive paste layer, and a second plating layer formed on the conductive paste layer, and the conductive paste layer has one conductive-paste-layer non-formation region with the first plating layer and the second plating layer directly bonded in the conductive-paste-layer non-formation region. The conductive-paste-layer non-formation region can be formed by application through a predetermined mask pattern. For the conductive-paste-layer non-formation region, a belt-shaped region extending in the lateral direction of the first plating layer **133***a* can be used.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, by sandwiching the conductive paste layer between the first plating layer and the second plating layer and directly bonding the first plating layer and the second plating layer in the conductive-paste-layer non-formation region, the adhesion of the conductive paste layer to the molded body can be improved, and the connection reliability can also be improved.

In the example described in this embodiment, as shown in FIG. **14**, the first plating layer **133***a* is formed substantially entirely on the first side surface **132***e*; however, the plating layers having the mesh or slit structure described in the third to fifth embodiments are also usable. Even in this case, the same effects as this embodiment are produced.

In the example described in this embodiment, as shown in FIG. **14**, the first plating layer **133***a* is formed substantially entirely on the first side surface **132***e*; however, the entire surface of the first plating layer **133***a* can completely be exposed, while a conductive paste layer is formed such that the conductive paste layer covers the first plating layer **133***a* of the first side surface in the periphery thereof, and the second plating layer can be formed on the conductive paste layer to directly bond the first plating layer and the second plating layer. Even in this case, the same effects as this embodiment are produced.

Eighth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the seventh embodiment except that a conductive paste layer has multiple conductive-paste-layer non-formation regions with a first plating layer and a second plating layer directly bonded in the multiple conductive-paste-layer non-formation regions.

FIG. **15** is a partially cutaway schematic cross-sectional view of a surface-mount inductor H according to this embodiment. A lead-out end part **141***b* is exposed on a first side surface **142***e* of a molded body **142**. An external terminal **145** includes a first plating layer **143***a*, a conductive paste layer **144**, and a second plating layer **143***b*. The first plating layer **143***a* is formed on the lead-out end part **141***b*, the conductive paste layer **144** having multiple conductive-paste-layer non-formation regions **144***a* is formed on the first plating layer **143***a*, and the second plating layer **143***b* is formed on the conductive paste layer **144** to cover the conductive paste layer **144**. The first plating layer **143***a* and the second plating layer **143***b* are directly bonded in the multiple conductive-paste-layer non-formation regions **144***a* arranged in the longitudinal direction of the first plating layer **143***a*. For each of the conductive-paste-layer non-formation region, a belt-shaped region extending in the lateral direction of the first plating layer **143***a* can be used.

According to this embodiment, the same effects as the seventh embodiment are obtained. Furthermore, since the first plating layer and the second plating layer are directly bonded in the multiple conductive-paste-layer non-formation regions, the adhesion of the conductive paste layer to the molded body can further be improved, and the connection reliability can also be improved.

In the example described in this embodiment, as shown in FIG. **15**, the first plating layer **143***a* is formed substantially entirely on the first side surface **142***e*; however, the plating layers having the mesh or slit structure described in the third to fifth embodiments are also usable. Even in this case, the same effects as this embodiment are produced.

In the example described in this embodiment, as shown in FIG. **15**, the first plating layer **143***a* is formed substantially entirely on the first side surface **142***e*; however, the entire surface of the first plating layer **143***a* can completely be exposed, while a conductive paste layer is formed such that the conductive paste layer covers the first plating layer **143***a* of the first side surface in the periphery thereof, and the second plating layer can be formed on the conductive paste layer to directly bond the first plating layer and the second plating layer. Even in this case, the same effects as this embodiment are produced.

Ninth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except that a conductive paste layer is formed on an upper edge portion and a lower edge portion of a plating layer and on four surfaces adjacent to a first side surface. Description will be made with reference to FIG. **16**, and the portions common to the surface-mount inductor of the first embodiment will not be described.

FIG. **16** is a partially cutaway schematic cross-sectional view of a surface-mount inductor I according to this embodiment. A lead-out end part **151***b* is exposed on a first side surface **152***e* of a molded body **152**. A plating layer **153** is formed on the lead-out end part **151***b*. A conductive paste layer **154** is formed on an upper edge portion and a lower edge portion of the plating layer **153** and on four surfaces adjacent to the first side surface.

According to this embodiment, the same effects as the first embodiment are obtained. Furthermore, since the conductive paste layer is formed on the upper edge portion and the lower edge portion of the plating layer instead of the entire surface of the plating layer, an amount of the expensive conductive paste used can be reduced.

Tenth Embodiment

A surface-mount inductor according to this embodiment has the same structure as the first embodiment except that a bent portion is formed by leading out a lead-out end part of a coil from a first side surface and bending a tip portion led out into contact with a metal magnetic material powder exposed portion formed on the first side surface, and that while the lead-out end part is fixed to a molded body by the bent portion, the insulating coating of the bent portion is removed to form a plating layer.

According to this embodiment, the same effects as the seventh embodiment are obtained. Furthermore, by forming the plating layer on the bent portion, the bonding area is increased, and the bonding strength can further be improved. Additionally, as compared to when the lead-out end part of the coil is exposed on the first side surface, a tolerance becomes larger in terms of arrangement of the lead-out end part at the time of manufacturing of the molded body, so that an effect of facilitating the manufacturing of the molded body is also obtained.

In the surface-mount inductors according to the second to ninth embodiments, the lead-out end part of the coil can be led out from the first side surface to form the bent portion. Even in this case, the same effects as this embodiment are produced.

Eleventh Embodiment

This embodiment is an example of a surface-mount inductor J having two coils embedded in a molded body. FIGS. **17**, **18**, and **19** show a transparent schematic top view, a schematic side view, and a schematic bottom view, respectively, of the surface-mount inductor J.

In a molded body **162**, two coils **160**, **161** formed by winding conductive wires are buried in the length direction of the molded body **162**. The one coil **160** is a coil including a winding part **160***a* in which a conductive wire is wound such that both ends are arranged in directions opposite to each other along an outer circumferential surface of the coil, and a pair of lead-out end parts **160***b*, **160***b* disposed at both ends of the winding part **160***a* and made up of non-winding portions. Similarly, the other coil **161** includes a winding part **161***a* and a pair of lead-out end parts **161***b*, **161***b* disposed at both ends of the winding part **161***a* and made up of non-winding portions. FIG. **17** shows an example of two-tier outside-to-outside winding. The length direction of the molded body in this embodiment refers to a direction of extension of a straight line orthogonally intersecting with a straight line connecting the lead-out end parts at both ends of the coil.

On a third side surface **162***g* and a fourth side surface **162***h* oppositely arranged in the width direction of the molded body **162**, a pair of lead-out end parts **160***b*, **160***b* of the coil **160** is respectively exposed, while a pair of lead-out end parts **161***b*, **161***b* is also exposed. Plating layers (not shown) are respectively formed over the exposed surfaces of the lead-out end parts **160***b*, **160***b* and portions of the third side surface **162***g* and the fourth side surface **162***h*. On the plating layers, a pair of conductive paste layers (not shown) made of a solidified conductive paste is formed, extending in a belt shape on an upper surface **162***c* and side surfaces **162***g*, **162***h* and reaching a bottom surface **162***d* of the molded body **162**. Similarly, plating layers (not shown) are respectively formed over the exposed surfaces of the lead-out end parts **161***b*, **161***b* and portions of the third side surface **162***g* and the fourth side surface **162***h*. On the plating layers, a pair of conductive paste layers (not shown) made of a solidified conductive paste is formed, extending in a belt shape on the upper surface **162***c* and the side surfaces **162***g*, **162***h* and reaching the bottom surface **162***d* of the molded body **162**. As a result, the lead-out end parts **160***b*, **160***b* at both ends of the coil **160** are respectively connected via the plating layers to the pair of conductive paste layers. The plating layers and the conductive paste layers constitute a pair of external terminals **165**, **165**. Similarly, the lead-out end parts **161***b*, **161***b* at both ends of the coil **161** are respectively connected via the plating layers to the pair of conductive paste layers, and the plating layers and the conductive paste layers constitute a pair of external terminals **166**, **166**. In this embodiment, the third side surface **162***g* and the fourth side surface **162***h* mean opposite side surfaces with which a straight line connecting the lead-out end parts at both ends of the coil intersects.

According to this embodiment, even when two coils are used, the surface-mount inductor having the external terminals with high connection reliability can be provided.

What is claimed is:

1. A surface-mount inductor comprising:

a molded body containing a metal magnetic powder;

at least one coil buried in the molded body such that lead-out end parts at both ends of the coil are at least partially exposed on a surface of the molded body; and

an external terminal formed over an exposed surface of each of the lead-out end parts and a metal magnetic powder exposed portion formed at least around the exposed surface, the external terminal at least including a first plating layer formed over the metal magnetic powder exposed portion and the exposed surface of the lead-out end part, and a conductive paste layer formed on the first plating layer and made of a solidified conductive paste,

wherein the external terminal includes the first plating layer, the conductive paste layer, and

a second plating layer formed on the conductive paste layer,

the conductive paste layer has one or more conductive-paste-layer non-formation regions, and

the first plating layer and the second plating layer are directly bonded in the conductive-paste-layer non-formation regions.

2. The surface-mount inductor according to claim **1**, wherein:

the molded body has a rectangular shape having upper and bottom surfaces opposite to each other and four side surfaces, and

the lead-out end parts at both ends are respectively exposed on first and second side surfaces opposite to each other.

3. The surface-mount inductor according to claim **2**, wherein:

the metal magnetic powder exposed portion is formed entirely on the first side surface and the second side surface other than the exposed surfaces of the lead-out end parts, and

the first plating layer and the conductive paste layer are formed entirely on the first side surface and the second side surface including the exposed surfaces of the lead-out end parts.

4. The surface-mount inductor according to claim 2, wherein the lead-out end parts at both ends of the coil are led out from the first and second side surfaces opposite to each other.

5. The surface-mount inductor according to claim 1, wherein the first plating layer has a mesh structure.

6. The surface-mount inductor according to claim 1, wherein the first plating layer has a slit structure.

7. The surface-mount inductor according to claim 1, wherein:

the molded body has a rectangular shape having upper and bottom surfaces opposite to each other and four side surfaces, and

the lead-out end parts at both ends are respectively exposed on first and second side surfaces opposite to each other.

8. The surface-mount inductor according to claim 1, wherein the first plating layer has a mesh structure.

9. The surface-mount inductor according to claim 1, wherein the first plating layer has a slit structure.

* * * * *